WATER & SEWAGE WORKS

CHICAGO'S OLD WATER TOWER

1869-1949

From Calgary to Rio... St. John to San Diego..... It's LOCK JOINT

Throughout the Western Hemisphere, Lock Joint has established its reputation as the pressure pipe of unfailing service.

Lock Joint pressure pipe is supplied in four tested and proved designs, perfected through constant research.

★ ★

★ REINFORCED CONCRETE PRESSURE PIPE ★

★ REINFORCED CONCRETE CYLINDER PIPE ★

★ PRESTRESSED CONCRETE CYLINDER PIPE ★

★ REINFORCED CONCRETE SUBAQUEOUS PIPE ★

★ ★

Whatever your water supply line problem may be, one of these four standard Lock Joint designs is certain to satisfy your requirements and give lasting service.

Made in all standard diameters from 16" to 150", Lock Joint Pressure Pipe is designed for all pressures common to American water works practice.

You are invited to inquire at any of our offices for complete information.

SCOPE OF SERVICES:—Lock Joint Pipe Company specialises in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains in a wide range of diameters as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.

LOCK JOINT PIPE COMPANY

Est. 1905

P. O. Box 269, East Orange, N. J.

PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kansas

BRANCH OFFICES: Cheyenne, Wyo. • Denver, Colo. Kansas City, Mo. • Valley Park, Mo. • Chicago, Ill. Rock Island, Ill. • Wichita, Kan. • Kenilworth, N. J. Hartford, Conn.

LOCK JOINT *Reinforced Concrete* PRESSURE PIPE

WATER AND SEWAGE WORKS. Reg. U.S. Patent Off. May, 1949. Volume 96. Number 5. Published monthly by Gillette Publishing Co., at 404 North Wesley Ave., Mount Morris, Ill. Per copy, 25c; except *this issue*, 50 cents. Subscription rate: United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as second-class matter March 4, 1948, at the post office at Mount Morris, Illinois, under the Act of March 3, 1879. Executive and business offices, 22 W. Maple St., Chicago 10, Illinois. Editorial office, 155 E. 44th St., New York 17, N. Y.

PITTSBURGH-EMPIRE

Pittsburgh Arctic
Disc Meter

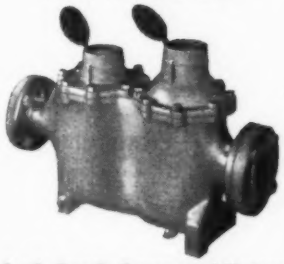
Empire Oscillating
Piston Meter
Type 14

Empire Oscillating
Piston Meter
Type 12

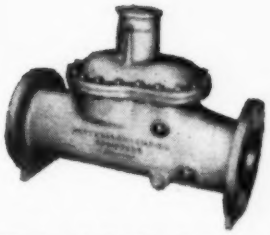
Pittsburgh Tropic
Disc Meter

Pittsburgh Disc Meter
Large Capacity Type

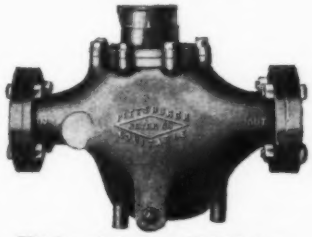
Empire Oscillating
Piston Meter
Type 16



Arctic-Tropic Compound Meter
Two Register Type



Pittsburgh-Empire Compound
Meter Single Register Type



Pittsburgh Eureka "B" Meter
Current Type

We cordially invite

the members of the American Water Works Association to meet their friends during the annual convention at our headquarters.

Hotel Stevens, Chicago, Ill.

ROCKWELL

PITTSBURGH EQUITABLE METER DIVISION

Rockwell Manufacturing Company • Pittsburgh 8, Pa.

Atlanta Boston Chicago Houston Kansas City Los Angeles
New York Pittsburgh San Francisco Seattle Tulsa

Bulletin on POROUS MEDIA

by CARBORUNDUM
TRADE MARK

NO. 2 JUNE, MAY, 1949

What About Clogging of Porous Plate Filter Underdrains?

Since the introduction of the porous underdrain system 15 years ago, this question has often been raised. Wide experience during that extended period has proved *there is no clogging under normal conditions and when plates are properly applied.*

A few trials and installations have been made with subnormal operation or under special conditions. Here operators desired benefits offered by ALOXITE aluminum oxide porous plates through elimination of all graded gravel. But unless advantages outweigh possible clogging difficulties, these unusual practices should be avoided:

1. Use of raw water (containing suspended solids) for backwashing. This could clog underside of plates.
2. Inadequate coagulation and settling or exceptionally high rates of filtration with coarse filter media. This may force solids or fine floc through to porous plates. Most of it would pass through, but some could accumulate in pores over a long period.
3. Little or no sedimentation following aeration of water containing iron and manganese. Filter media is unable to remove all hydroxides. Some will accumulate within underdrains.
4. Application of highly unstable water to filters in lime softening plants where carbonate incrustation may extend beyond the bottom of the filter media. It is possible that pores of plates will become coated and ultimately plugged. Control of this condition is practical and economical.

Engineers and superintendents will normally avoid all of these conditions through standard and efficient practice.

Properties of ALOXITE Porous Media

MATERIAL	Ceramically bonded crystalline aluminum oxide grain of controlled sizes.
GRADES (Pore size)	**Filter Underdrains**... coarse and very coarse. **Direct Filtration**... range from very fine to medium. **Diatomite Support**... range from fine to medium. **Air (gas) Diffusion**... range from fine to coarse (permeability from 10 to 120.)
SOLUBILITY	**In Water and Air**... insoluble at all normal operating temperatures. **In Acids**... generally resistant at all operating temperatures, except to hydrofluoric acid. **In Alkaline Solutions**... ceramic bonds are progressively soluble with time and temperature increases.
STRENGTH	Transverse breaking strength is relatively good ranging from 1000 lbs./sq. in. (coarse grades) to 3000 lbs./sq. in. (fine grades).
REFRACTORINESS	All grades withstand up to 900° C. without softening.
THERMAL SHOCK RESISTANCE	Withstand changes up to 20° C./hr. (Where more severe heat shock exists, ceramically bonded silicon carbide porous media are available.)
POROSITY	Ratio of pore volume to total volume of all grades approximately 35%.
WEIGHT	Approximately 0.09 lbs./cu. in.

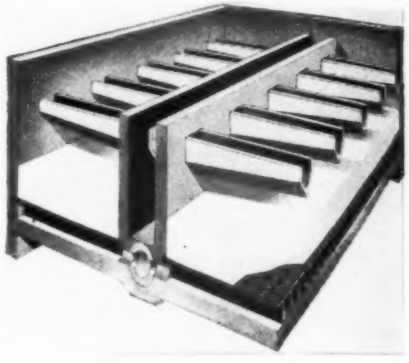
"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company

POROUS BOTTOM TRICKLES...

Alum clogging has been eliminated easily, where it occurred in 2 or 3 cases, by an overnight treatment with sodium hydroxide. Filter media is not removed and is also cleaned.

Quite a few of more than 200 successful ALOXITE underdrain installations are in iron removal plants. These have good aeration and settling.

At least 3 ALOXITE underdrain installations are in highly satisfactory lime softening plants. Close control and regular backwash have avoided $CaCO_3$ incrustation. If clogging occurs, plates can be cleaned with acid.



The list of successful ALOXITE underdrain installations is growing. Saving in filter maintenance due to gravel elimination is the principal reason. And usually there are many added benefits.

TECHNICAL DATA
on porous media and their application

is available on request. You may obtain any or all of the following engineering bulletins by writing Dept. O-59.

No. 1—Aeration of Sewage and Water.

No. 2—Underdrain Systems for Filters and Softeners.

No. 3—General Catalog information.

THE CARBORUNDUM COMPANY
Refractories Division
PERTH AMBOY, NEW JERSEY

WATER & SEWAGE WORKS

WATER SUPPLY—SEWAGE DISPOSAL—INDUSTRIAL WASTE TREATMENT

E. S. GILLETTE, Publisher

L. H. ENSLOW, Editor

COMING

This Month's Cover

Chicago, the place of A.W.W.A.'s 1949 Convention, has no landmark more revered than its Old Water Tower. Although it has not been used since 1903, the citizenry of Chicago has blocked every proposal for its removal during the tower's 81-year existence. A castellated monument to civic progress, it has seen Chicago expand from a population of a bare quarter-million to almost four million.

The Water Tower, completed in 1869, just four years after the Civil War, was but two years old when it withstood the Great Chicago Fire of 1871 unscathed, and as the only major structure in the path of the main holocaust to survive.

Standing 154 feet high, the tower proper has walls 10 feet thick at its base, tapering to a 1-foot thickness at the top. Inside, the 3-foot diameter wrought-iron standpipe served merely as a means of absorbing the pressure pulsations created by the giant steam pumps.

The tower, revealing the military engineering influence on civic structures of the time, was designed by Wm. A. Boyington, architect-engineer, and was built of native limestone under the jurisdiction of the famed City Engineer of Chicago, Ellis S. Chesborough, 1855-1879.

For having had this unusual night view taken of the Old Water Tower, with the halo effect, for our cover picture, we are indebted to W. W. DeBerard, City Engineer of Chicago.

Ecusta's Modern Filtration Plant

Down in Pisgah National Forest, high up in the Blue Ridge Mountains of North Carolina, is a modern filtration plant which would be the pride and joy of *any* municipality. In this instance, however, the spic-and-span water purification plant serves an industry which rates excellence of water supply ahead of that of any other raw material entering into the manufacturing process. This filtration plant supplies the vast volume of water required in the production of the highest quality of cigarette papers used on a variety of cigarettes. So impressed were we with this plant, and its scrupulous maintenance and operation, that we have after a number of tries secured the forthcoming article by

H. F. FINCK and M. M. MATTHEWS, Eng'rs.
The Ecusta Paper Corp., Pisgah Forest, N.C.

A Report on Porous Filter Bottoms

Brings information on this type of rapid sand filter bottom up to date. Not since the last summary made in 1945 has there been such a review of the application and performance history of these porous plate underdrains which eliminate the gravel bed and possess other advantages. Illustrations add value and interest to this report by

FRANK C. ROE, Development Engineer,
The Carborundum Co., Perth Amboy, N.J.

The 26th Ward Sewage Treatment Works, Brooklyn, N.Y.

Is about to become one of the newest plants in the country instead of a fifty year old landmark. To serve 480,000 persons in the heart of Brooklyn, the new plant will employ the activated sludge process and will thus make possible the use of Jamaica Bay for recreational purposes. The complete story of the old plant being replaced by this modern one is told by—

S. W. STEFFENSEN, Project Mgr.
N. Y. City Dept. Pub. Wks.

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(Member—Audit Bureau of Circulation and Associated Business Papers.)

We hope you'll still keep your guard up!

THIS IS HOW you greeted us when we first introduced you to the General Electric Disposall.*

And it was the correct stance—the right stand—to take in the face of a completely new and revolutionary sanitation idea.

Rightly, you put the burden squarely on us to prove that the Disposall method of garbage elimination would benefit your community in every way. It was not enough that the Disposall would take all food waste, shred it into tiny particles and flush it away into sewer or septic tank.

You wanted "show me" evidence that there would be no danger of sewage stoppages, or of any of the problems which might affect normal sewage-works operation.

We believe that we have convinced sanitation officials in cities, large and small, as to the merits of the Disposall. It has been accepted almost everywhere as a clean, sanitary, economical method of garbage elimination. When necessary, sanitation codes have been revised to permit its use in the community.

Doubtless, there are other food-waste shredders that will be able to convince you of their efficiency and economy. Appliances that will meet the strictest examination.

But, because the Disposall is the pioneer in the field of scientific garbage elimination—and has proved itself in the laboratory and in countless homes—we believe you will be interested in reading the specifications below. They are the very specifications used in the development and perfection of the General Electric Disposall.

They may be of use to you in drawing up your own list of requirements.

GENERAL ELECTRIC'S SPECIFICATIONS FOR ITS FOOD-WASTE SHREDDER— THE DISPOSALL

1. *The Disposall has a flow interlock that permits operation with cold water only.*

This requirement is necessary because experience has shown that only with cold water will greases become congealed within the cylinder. With congealed grease broken up into small particles, mixed with food waste and carried off through the drain, there can be little tendency for greases to adhere to the walls of the pipe.

2. *The discharge from the Disposall remains in a fluid state. The correct relationship between the amount of food waste and tap water is maintained by controlled shredding.*

This equalization of water and food waste permits the ready flow of effluent through traps, drain, or soil lines in a manner to prevent clogging.

3. *The Disposall shreds food waste to a uniform size, to meet the following requirements: 100% shall pass a ½-inch screen. At least 90% shall pass a ¼-inch screen. Not more than 5% shall pass a #40 sieve.*

(Screens should be the United States standard, and weight should be taken on a dry basis.)

In other words, the particles of shredded food waste are of the correct size, to permit effective sewage clarification and sludge digestion at the treatment plant.

4. *The food-waste shredder is self-scouring, with no fouling surfaces.*

This method prevents objectionable odors; keeps the unit clean as a whistle.

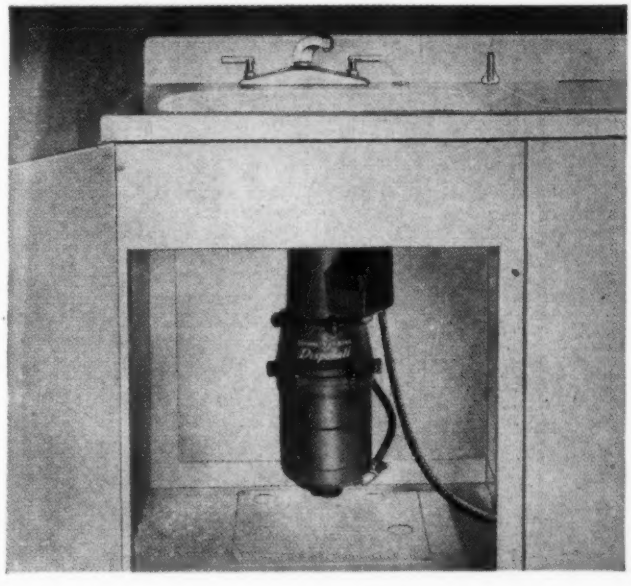
5. *The food-waste shredder provides maximum protection against electrical or mechanical hazards.*

As a safety measure, the shredding compartment is inaccessible during operation.

6. *The food-waste shredder is designed for connection to the plumbing, in accordance with the local plumbing code, and should be free from any cross-connection.*

This regulation eliminates any makeshift, homemade hook-ups, and permits the proper operation from sink to sewage treatment plant.

For further information about the Disposall method, simply write to Department WSW 495, General Electric Company, Bridgeport 2, Connecticut.



The General Electric Disposall is easily installed in almost any sink. Here it is shown installed in our electric sink. Food waste is scraped into drain opening, and safety cover is placed in position. The cold-water tap is then turned on, starting the Disposall operation. Food waste is shredded and flushed away automatically.

P. S. Thousands of Disposalls are operating successfully on private septic tank systems.

Disposall

*General Electric's registered trade-mark for its food-waste disposal appliance.

CONVERTS FOOD WASTE TO SEWAGE—ELIMINATES "GARBAGE"

GENERAL ELECTRIC

Worthington-Gamon

WATCH DOG WATER METERS

The meter used by thousands of municipalities in the U. S. and abroad.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WATCH DOG WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 gpm up; frost-proof and split case in household sizes. Disc type, Turbine type or Compound type. Write for Bulletin.

WORTHINGTON-GAMON METER COMPANY

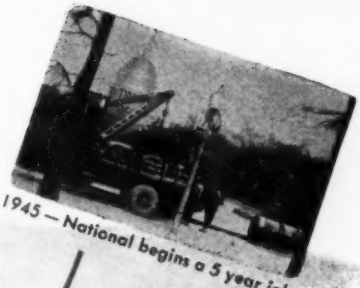
296 South Street, Newark 5, New Jersey

Subsidiary of

WORTHINGTON

PUMP AND MACHINERY CORPORATION

Teddy Roosevelt was president when we cleaned Washington's mains in 1907.



1945 — National begins a 5 year job.

Cleaning controlled by 2-way radio.

NATIONAL CLEANING AGAIN

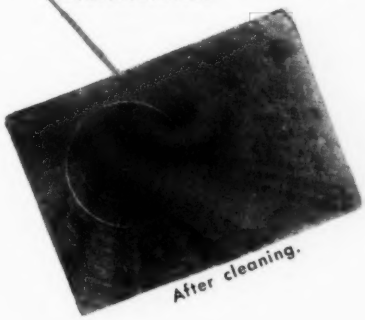
lowers pumping costs

increases volume

increases water pressure

FOR WASHINGTON, D. C.

Before cleaning.



After cleaning.

Way back in 1907 and again in 1926 National successfully cleaned the water mains of Washington, D. C.

In 1945 a five year program to clean and recondition the entire water main system of Washington was begun and National in conjunction with the Centriline Corporation was successively awarded the cleaning contracts for 1945, 1946, 1947, 1948 and 1949—*in short, all the cleaning jobs to date.*

Tests made on those lines already cleaned and centrilined indicate a co-efficient of over 130 as against less than 90 before cleaning, resulting in lower pumping costs, increased volume and higher pressure.

Let us estimate the cost of restoring your lines to at least 95% of their original carrying capacity. Write today.

NATIONAL WATER MAIN CLEANING COMPANY

29

50 Church St., New York 7, N. Y.

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"City highly endorses Badger Meters and Testing Machines"

That's what the mayor of one Illinois city wrote to another, adding: "Operation of these meters has always been satisfactory and maintenance-cost very reasonable . . . in our meter shop, a Badger Testing Machine enables us to see the quality of our work, which was not possible before we bought the Testing Unit."

In over 5000 communities, waterworks men know that "It pays to BUY BADGER".

You will find a Badger Meter size and type for every waterworks service. Shown here are Model SC-IOT (for warm climates), and Model A-IOT (for cold climates) . . . sizes 5/8" to 1¼" . . . other models in sizes up to 12". Write for complete information and prices.

BE SURE TO SEE THE
BADGER METER EXHIBIT
at the AWWA Convention
BOOTH 27 AND 28

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BADGER Water METERS

ACCURACY • LOW-COST MAINTENANCE • DURABILITY • SENSITIVENESS

"Stay out of here folks.... this hot stove will fry you!"

WHEN the first gas range, with its promise of a cool kitchen, was exhibited at the Philadelphia Centennial Exposition in 1876, little did its sponsor dream of a market of 21,000,000 homes. For that is the extraordinary number of residential customers now served by gas for cooking, refrigeration, or home heating.

Water supply and sanitation also made extraordinary progress in the half-century since 1899, the year our Company was established. Today, 12,000 water works furnish 85 million people with a dependable supply of safe, palatable water. Over 6,000 sewage treatment plants contribute to the health of the nation.

In these three progressive branches of public service—gas, water supply and sanitation—are customers who have been buying pipe from us for 50 years. They know that we, also, have made signal progress, from decade to decade, in developing and perfecting better methods for the production of better pipe.

To those responsible for the great progress in water supply, gas and sanitation service and their contribution to better health and living over the past fifty years, America pays tribute.

U.S. CAST IRON PIPE

1899-1949
U. S. Pipe & Foundry Co
Makers for 50 years of cast iron pipe for water, gas and sewerage service.
General Offices: Burlington, N. J.

CHICAGO

South District Filtration Plant

(Completed in 1947)

DEPARTMENT OF PUBLIC WORKS
BUREAU OF ENGINEERING
W. W. DeBERARD, City Engineer

ALVORD, BURDICK & HOWSON
Consultants

GREELEY & HANSEN
Consultants

Chicago's new South District Filtration Plant, the largest in the world, supplies filtered water to over 1,500,000 people in Chicago and its suburbs. *Builders-Providence filter equipment* was installed in this giant plant by *Pitt Construction Company*. For Bulletins describing Builders waterworks equipment, address Builders-Providence, Inc., (Division of Builders Iron Foundry), Providence 1, R. I.

Builders-Providence equipment furnished for South District Filtration Plant:

- 80 20" Venturi Rate of Flow Controllers
- 76 3-dial Filter Gauges (Sand Expansion, Loss of Head, Rate of Flow)
- 160 Pneumatic Transmitters
- 4 Master Filter Gauges
- 4 20-unit Pneumatic Summators
- 2 2-unit Pneumatic Summators
- 10 30" Double Dial Illuminated Gauges
- 4 30" Back Wash Venturi Controllers with Pneumatic Transmitters and Recorders
- 4 16" Surface Wash Venturi Tubes with Pneumatic Transmitters and Recorders

Illustration shows Builders Master Gauge and Operating Table.

BUILDERS PROVIDENCE
Instruments

as a matter of record . . .

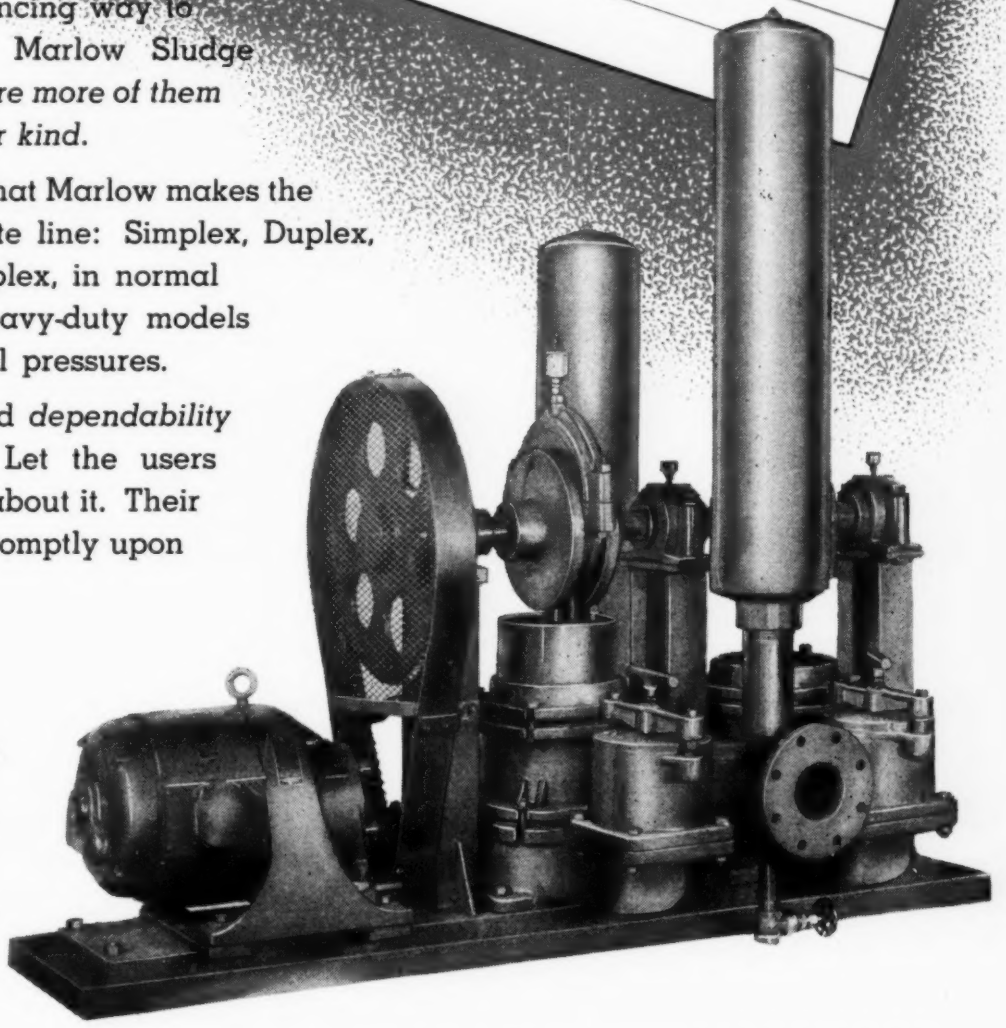
PUMP DATA FILE

MOST SLUDGE PUMPS NOW IN USE ARE MARLOWS

Quickest, most convincing way to state the case for Marlow Sludge Pumps is this: *there are more of them in use than any other kind.*

One reason may be that Marlow makes the world's most complete line: Simplex, Duplex, Triplex and Quadruplex, in normal duty and also in heavy-duty models for greater-than-usual pressures.

Another is the proved *dependability* of Marlow pumps. Let the users nearest you tell you about it. Their names will be sent promptly upon request.

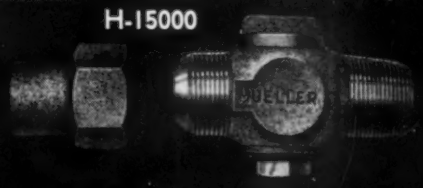


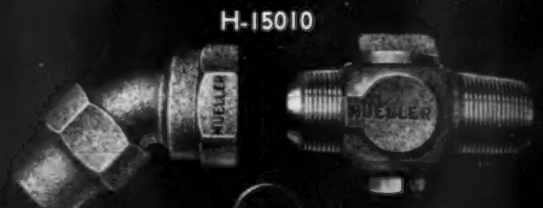
write for

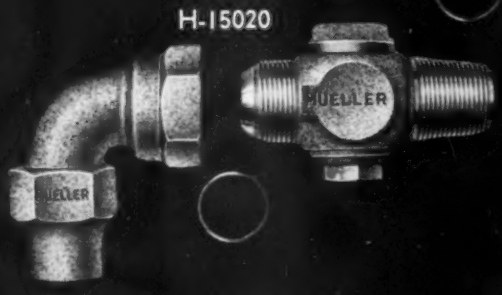
- ✓ Marlow Sludge Pump Bulletin.
- ✓ Name of Marlow users nearest you.
- ✓ Name of your Marlow Pumps distributor.

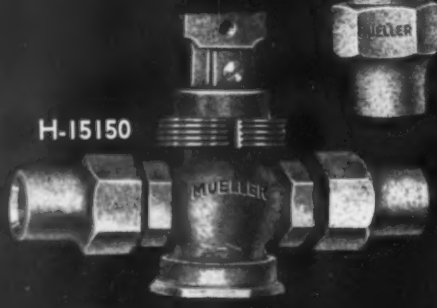
MARLOW PUMPS · · RIDGEWOOD NEW JERSEY

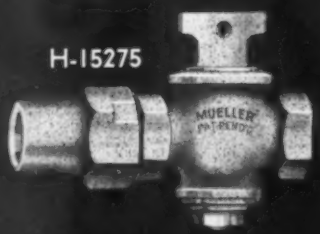
YOUR BEST ASSURANCE OF DEPENDABLE PERFORMANCE









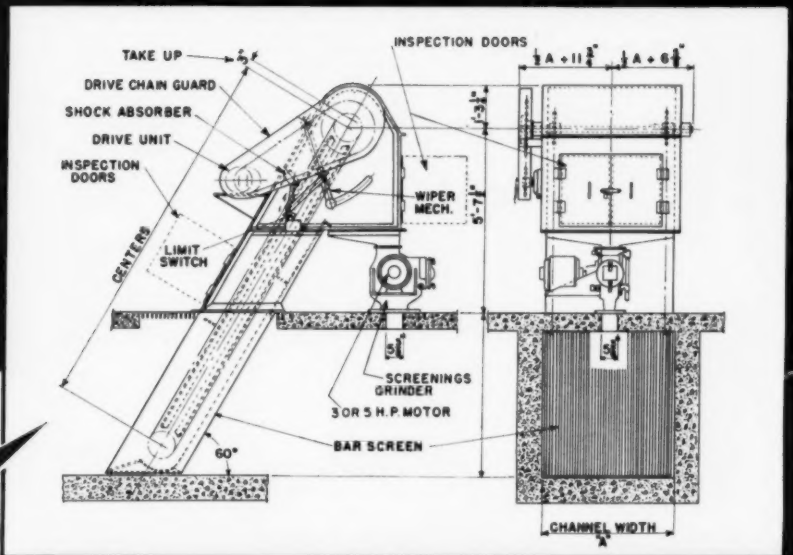


The installation of Mueller Ground Key Corporation and Curb Stops is your best assurance of dependable performance. They are cast with heavy sections from high copper content bronze which gives maximum resistance to corrosion. Precision grinding and lapping of the key into the body affords a leak-proof fit and easy turning. These are just a few of the many outstanding features of Mueller Ground Key Corporation and Curb Stops. Ask your Mueller Representative to give you complete details or write us direct.

MUELLER CO.

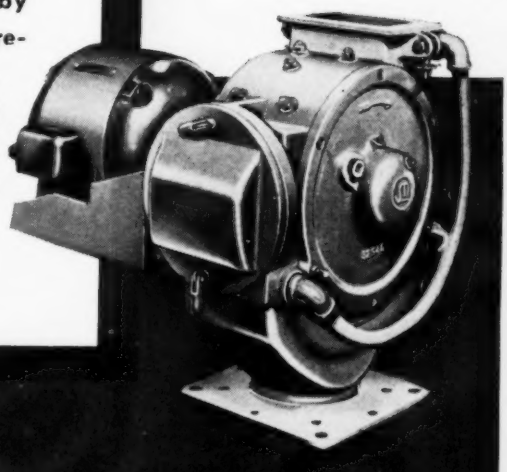
MAIN OFFICE AND FACTORY.....DECATUR, ILLINOIS
OTHER FACTORIES: *Los Angeles, Cal.; Chattanooga, Tenn.; Sarnia, Ont. Canada*

THEY WORK TOGETHER...



Efficient apparatus for the removal of coarse suspended matter and disposal is this Jeffrey Screen and Grinder combination. It takes care of the final disposal of screenings so important in the treatment of sewage. Screenings collected and disposed of by grinding them to a pulp and returning them to the sewage. This combination is designed for moderate-size treatment plants. We will be glad to go into detail.

Above—Dimension drawing of screen with screenings grinder arranged for hand feeding of screenings.



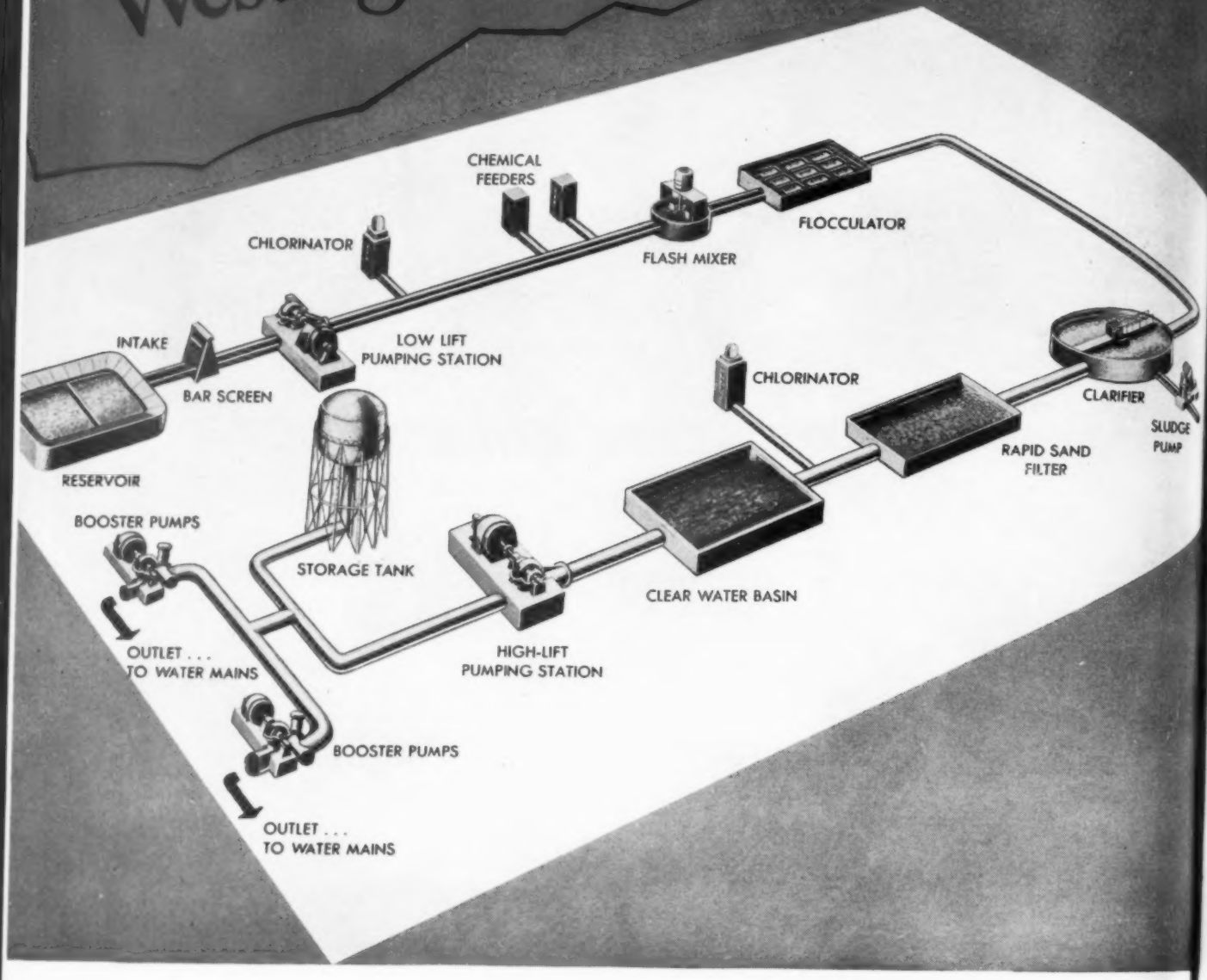
JEFFREY

ESTABLISHED 1877

YOU CAN BE SURE.. IF IT'S

Westinghouse

KEY TO MORE



"A TO Z" SOLUTION TO YOUR ELECTRICAL OR POWER REQUIREMENTS . . . *FOR HIGHER OPERATING EFFICIENCY*

Whether your plans call for expansion, modernization or a completely new plant, you will find advantages in using the Westinghouse background in waterworks engineering—regardless of the size of the contemplated project.

Westinghouse engineers will work with you to obtain highest operating efficiency through the proper *selection, application* and *co-ordination* of the complete electrical drive.

Westinghouse equipment will provide you assurance of long-time, trouble-free service.

Westinghouse servicing will minimize and simplify your maintenance problems.

Typical of case histories where Westinghouse waterworks engineering has been job-proved is the City of Dallas 120 mgd Bachman plant, which is completely Westinghouse-electrified.

For help on your waterworks drive problem, call your Westinghouse office, or write today to Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-94746

OPERATING EFFICIENCY

"WESTINGHOUSE-EQUIPPED THROUGHOUT" MEANS SIMPLIFIED ORDERING, QUICKER INSTALLATION, MORE EFFICIENT OPERATION

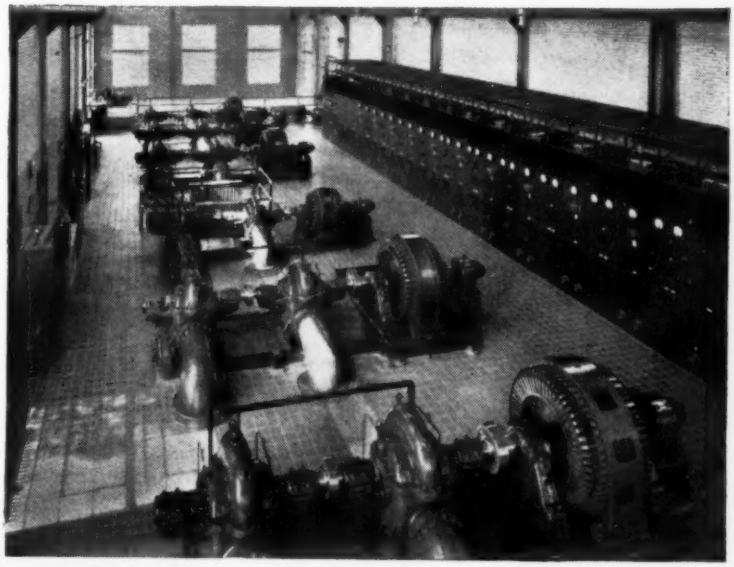
Putting power to work *efficiently* can be a major problem—or a simple one. When items must be selected, ordered and received from many sources, it means many chances for costly errors and delays . . . divided responsibility—or none at all—for performance of installed equipment.

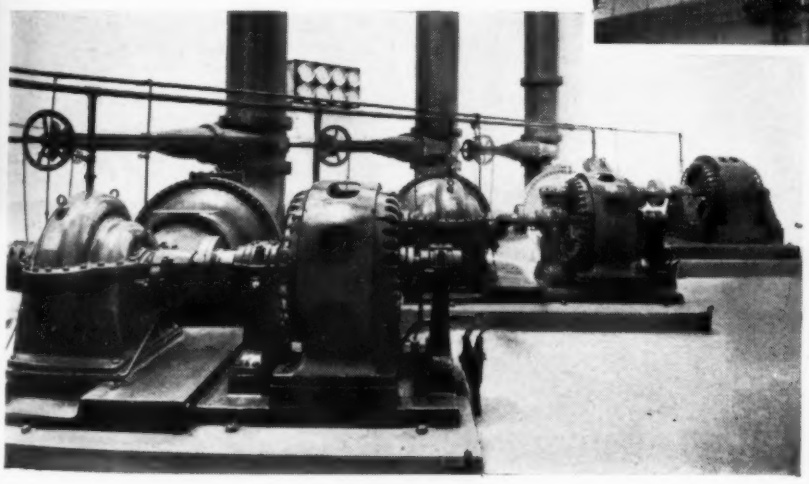
Westinghouse offers the way to simplify the job. From equipment for generation of electrical or steam power, to the most specialized types of drives and control for its utilization, Westinghouse provides a single source of supply . . . one broad pair of shoulders competent to take responsibility for performance of all parts of the job.

Here is one of many examples where Westinghouse unit responsibility is preventing headaches . . . saving money . . . assuring *higher operating* efficiency:

MAIN PUMPING FLOOR of the 120 mgd Bachman Waterworks, City of Dallas, Texas. This plant has 15,225 hp in Westinghouse motors, supplemented by Westinghouse switchgear and other apparatus. The satisfactory service rendered is evidenced by 12 years' operation without repairs of any kind to electrical equipment, with a maintenance cost which has averaged less than 2c per hp.

In the center are five 800-hp and one 400-hp Westinghouse synchronous motors. At the left and right-rear two Westinghouse motor generator sets (one of which is a standby unit) furnish excitation for four 500-hp and three 900-hp Westinghouse motors located in the basement. At the right is shown part of the Westinghouse controls for the entire plant.





LEFT: Basement floor, showing three of four 500-hp Westinghouse motors, each of which drive a 30 mgd raw-water pump. Three 900-hp Westinghouse vertical motors, driving clear-water pumps, are also located on this floor but are not seen in this picture.

Westinghouse

Ask DETROIT About C

In 1854—ninety-five years ago—Detroit laid her first 6-inch cast iron pipe. Of all the 6-inch cast iron pipe laid from that date, 96.2% is still in service.

Fourteen years earlier, in 1840, Detroit laid her first 8-inch cast iron pipe and 97.9% of all the 8-inch cast iron pipe laid during the past 109 years is still in service. A portion of a 10-inch cast iron transmission line laid in 1838 is still in service.

Detroit is one of the cities included in the survey of "Survival and Retirement Experience with Water Works Facilities," including cast iron water mains, conducted under the auspices of the American Water Works Association, the New England Water Works Association and the Institute of Water Supply Utilities. The recently published report of the findings of the survey shows that 96% of all 6-inch and larger cast iron water mains ever laid in 25 representative cities are still in service.

Detroit's experience with cast iron water mains, therefore, while remarkable, is not exceptional.

We shall be glad to send on request a copy of our brochure "Survival and Retirement Experience with Cast Iron Water Mains," reprinted by permission. Address Cast Iron Pipe Research Association, Thomas F. Wolfe, Engineer, 122 South Michigan Avenue, Chicago 3, Illinois.

96%

CAST IRON PIPE

Cast Iron Pipe!

SERVES FOR CENTURIES

Engineering Facts about

Johns-Manville TRANSITE* PRESSURE PIPE

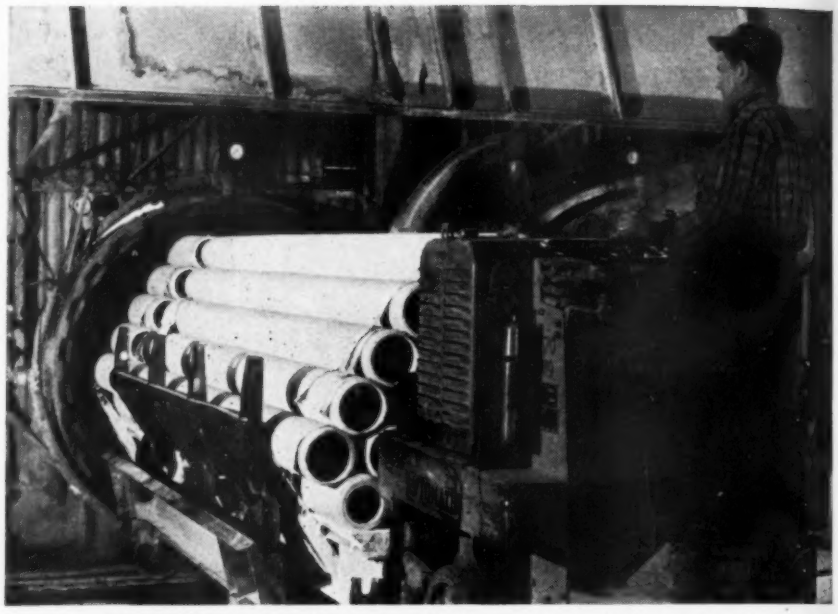
Resistance to Corrosion ... an index of long life

Ability to withstand corrosion is the most important single measure of the durability or life expectancy of an underground water pipe material. Two factors—both inherent in the pipe itself—contribute to Transite's exceptional ability to resist corrosion. These are:

1. The inherently corrosion-resistant materials of which Transite is made.

2. The specially developed manufacturing process — employed exclusively by Johns-Manville—which imparts a high degree of chemical stability to the finished product.

In the manufacture of Transite Pipe, the three basic ingredients, asbestos fibres, cement and silica —all basically corrosion-resistant by nature—are consolidated under tremendous pressure to form a pipe wall of dense, uniform, homogeneous structure. After forming, the pipe is subjected to a special steam curing process.



A load of Transite Pipe about to enter the steam curing tanks. This step in the Johns-Manville manufacturing process contributes substantially to the corrosion resistance of the finished pipe—and, therefore, to its long service life.

Transite Pipe was first used by this large west coast city in 1933. Its exceptional corrosion resistance—an index of long life—has already made it possible for Transite to outlive other pipe several times over.

It is in this steam curing stage that so much is contributed to the stability and structural integrity of the pipe. Here under the action of pressure steam, Transite assumes a new chemical identity. The silica unites chemically with the free lime ordinarily associated with cement products and converts it into highly stable calcium silicates. As a result of this process, the cured pipe is unusually resistant to corrosive attack throughout its entire structure.

This intrinsic resistance to corrosion has been substantiated by numerous Transite installations. Some of these have been exposed to highly aggressive soils, both alkaline and acid, for many years. Many are now serving as replacements under conditions so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

Transite Pipe was installed in this Texas city ten years ago to replace another pipe material that had been destroyed by soil corrosion in 7 years. The Transite mains are still on the job today with a long useful life ahead of them.

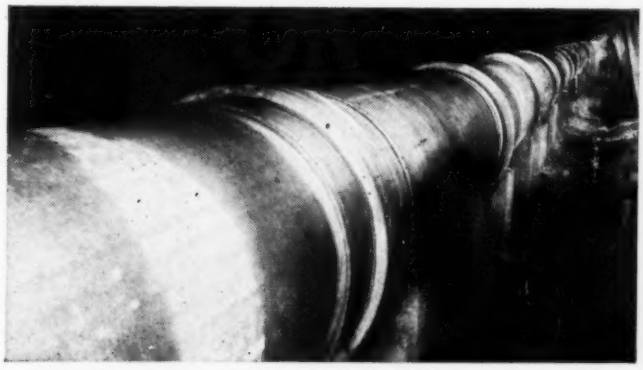
In one such installation, a Transite main installed during 1932 in an extremely corrosive soil was recently made the subject of careful study to determine its condition. Sections of the pipe, including couplings, were dug up and shipped to the factory for test. There was no evidence of deterioration. Pipe and couplings readily withstood the original factory pressure test, equivalent to four times the normal working pressure of the line.

Like thousands of other communities, this West Virginia city selected Transite Pipe because it promised assurance of maximum life. Today, after 14 years of service, the first installation of Transite has already fulfilled this promise by outlasting the pipe material previously used.

Certain types of industrial service provide an even more severe "proving ground" for the life expectancy of pipe materials, and here, too, Transite Pipe has demonstrated exceptional corrosion resistance. Coal mine service is a typical example. Here acid mine waters are frequently so corrosive that they have destroyed ordinary pipe materials in a matter of a few months or years. Yet Transite Pipe has handled these same waters under working pressure up to 150 lbs. for periods from 10 to 15 years with little, if any, indication of deterioration.

Corrosive soil conditions were so severe at this location in a prominent New England city that the life of the pipe material formerly used was only 15 years. Transite Pipe, put in as a replacement in 1934, continues to give the same efficient, dependable service as the day it was installed.

To evaluate the ability of pipe materials to withstand soil corrosion, the National Bureau of Standards has conducted an extensive series of field tests. These studies are based on examination of hundreds of pipe samples periodically removed from severely corrosive soils. In these and similar tests, Transite Pipe has consistently demonstrated its superior resistance to soil corrosion, confirming the long life expectancy which this asbestos-cement pipe has evidenced in thousands of water works installations.



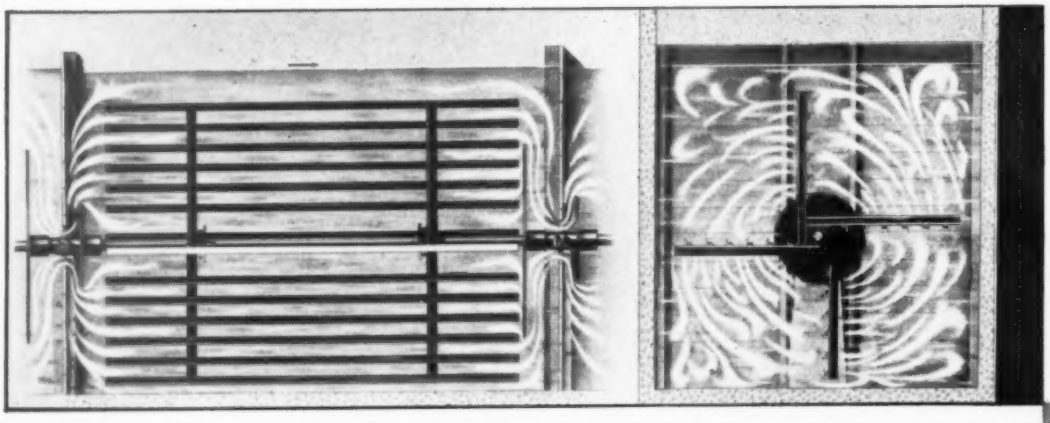
Transite's ability to provide long-term, dependable service is well illustrated by its performance in coal mines, where it consistently outlasts other pipe materials in carrying corrosive mine drainage waters. The 36" Transite line shown above has been conveying acid mine waters for 15 years.

For further details about Transite Pressure Pipe, write Johns-Manville, Box 290, New York 16, N. Y.

*Transite is Johns-Manville's registered trade mark for its asbestos-cement pipe and other products.

JOHNS-MANVILLE JM PRODUCTS

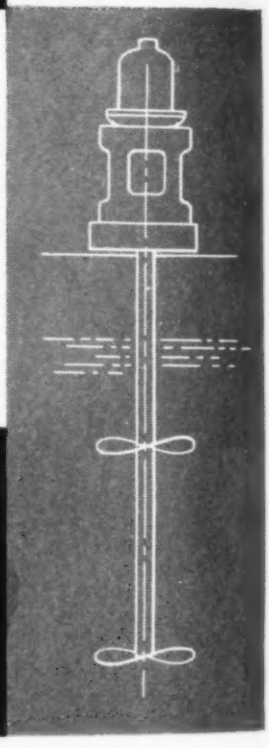
REX flocculation EQUIPMENT

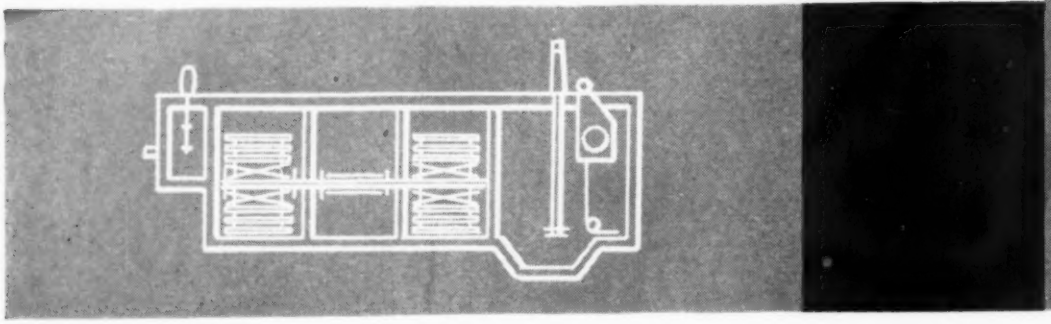


for uniform, efficient mixing

Rex Floctrol* Here's the greatest development in chemical mixing since the Langelier Multi-Stage Flocculation principle was introduced 25 years ago. The new Rex Floctrol is a unique combination of scientifically designed paddles, properly proportioned, rotating baffles and fixed partition walls with center ports, so arranged that thorough mixing is assured, and at the same time short-circuiting through the chamber is held to a minimum. Initial cost is low, and a minimum amount of chemical is required. Efficient use of horsepower, since none is wasted "bucking" the flow. Extremely flexible to suit any conditions. Fast, tapered mixing by zones assures large, readily settleable floc. Write for Bulletin No. 48-39.

*Reg. U.S. Pat. Off.





Rex Slo-Mixers The Rex Slo-Mixer is similar to the Rex Floctrol in design and advantages, except it does not use the solid baffle wall with central port and rotating circular baffle. It provides tapered mixing and efficiently produces the right turbulence for maximum floc formation with minimum chemical consumption. Rex Slo-Mixers are particularly suited to the flocculation of sewage or industrial waste in which grease is present. The baffle construction permits the passage of grease and scum to the clarifier for removal. Rex Slo-Mixers can be installed in basins of practically any dimension and shape to bring positive mixing, minimum short-circuiting, and low power consumption.

Rex Flash-Mixers Rex Flash-Mixers effect an almost instantaneous dispersion of chemical throughout the water. Installed in a small tank immediately preceding the flocculation tanks, Rex Flash-Mixers provide an exclusive double mixing action, combining slow rotation with a fast top-to-bottom turnover for thorough mixing. A one-minute detention period is usually sufficient. Rex Flash-Mixers are strongly built and precisely engineered to provide long life, quiet operation, and highly satisfactory performance. Chain Belt Company of Milwaukee—1610 W. Bruce St., Milwaukee 4, Wis.

CHAIN BELT REX COMPANY

SANITATION EQUIPMENT

Member of the Water and Sewage Works Manufacturers Association, Inc.

The Symbol of a Modern Water System

Horton elevated tanks provide service and economy consistent with the most advanced ideas of design and construction. They have been installed to "round out" the water supply systems of many municipalities by making possible the following advantages: uniform water pressure during peak loads; adequate reserve supply during power failure; lower pumping costs; increased capacity of water system; lower fire insurance rates.

The 500,000-gal. Horton elevated tank shown above serves the Warren, Ohio, municipal water system. Its radial-cone bottom design is particularly adaptable to the larger capacities where a tank with a smaller diameter would have an excessive range in head.

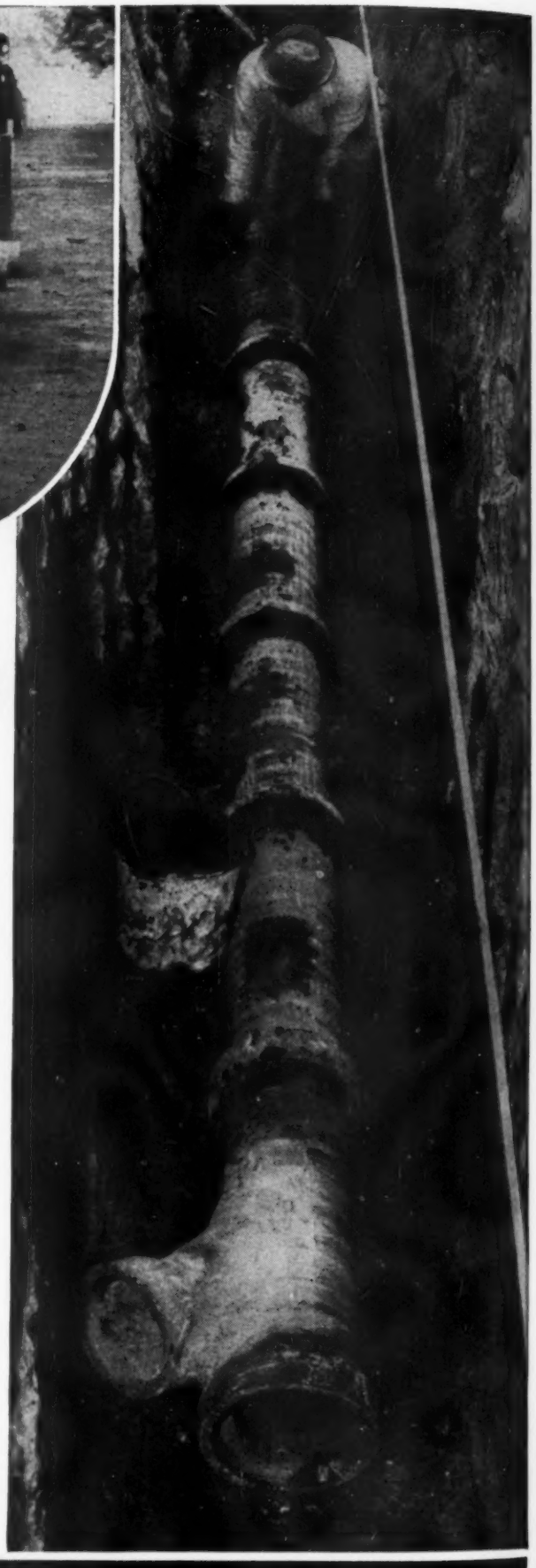
The Warren water system supplies a population of 60,000 people, whose average daily consumption is 7,667,900 gals. The source of the water supply is the Mahoning River. Electrically-driven low-lift pumps deliver raw water to a 10 mgd filter plant at the pumping station. Filtered water is pumped into the distribution system by electrically-driven centrifugal high lift units with a capacity of 18 mgd.

Horton welded steel tanks are available with radial-cone bottoms in capacities from 500,000 to 2,500,000 gals. or with ellipsoidal bottoms in standard capacities of 15,000 to 500,000 gals. If you're planning to install an elevated tank, write our nearest office for complete details. State capacity, height to bottom, and location.

CHICAGO BRIDGE & IRON COMPANY

Atlanta 3	2181 Healey Building	Detroit 26	1551 Lafayette Building	Philadelphia 3	1644-1700 Walnut Street Building
Birmingham 1	1586 North Fiftieth Street	Houston 2	2115 National Standard Building	Salt Lake City 1	1550 First Security Bank Building
Boston 10	1048-201 Devonshire Street	Havana	402 Abreu Building	San Francisco 11	1283-22 Battery Street Building
Chicago 4	2198 McCormick Building	Los Angeles 14	1555 General Petroleum Building	Seattle 1	1350 Henry Building
Cleveland 15	2262 Guildhall Building	New York 6	3390-165 Broadway Building	Tulsa 3	1646 Hunt Building

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PENNSYLVANIA



Sanitary Sewers of
CONCRETE PIPE
Are Economical

Memphis, Tennessee, in company with hundreds of other American cities, discovered years ago that the use of concrete pipe for sanitary sewers is economical. Since its first installation Memphis has placed in service more than 75 miles of concrete pipe sanitary sewers.

Concrete pipe has proven to be satisfactory for sanitary sewers in Memphis for the very same reasons that concrete pipe has been used so successfully in other cities for 70, 80 or 100 years.

Concrete pipe has the strength to resist severe impact and to sustain heavy overburdens. Its smooth interior finish resists abrasion and also provides maximum hydraulic capacity, while its uniformly dense structure and joints that can be made watertight assure minimum infiltration and leakage.

Concrete pipe sanitary sewers are moderate in first cost, have extra long life and cost little or nothing for maintenance. These three factors mean that concrete pipe gives true ***low-annual-cost*** sewer service.

●

Photos show two views of the installation of an 8″ sanitary sewer on Haynes Road, south of Park Avenue, Memphis. Chandler & Chandler were the contractors.

AMERICAN CONCRETE PIPE ASSOCIATION

228 NORTH LA SALLE STREET, CHICAGO 1, ILLINOIS

PRECISION CONTROL

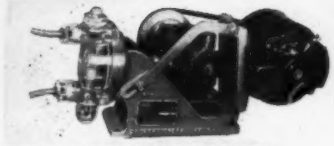
WITH

% PROPORTIONEERS %

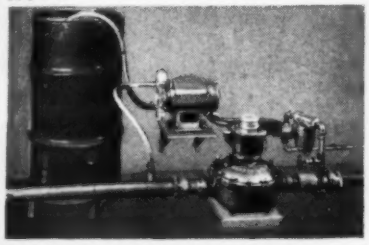
Positive Displacement Proportioning Pumps

Diatomaceous Earth Filters

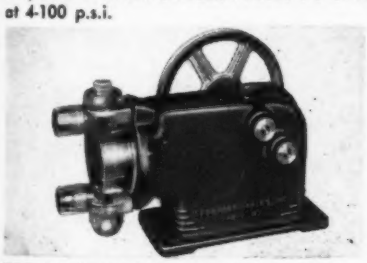
pH CONTROL
COAGULATION CONTROL
FILTRATION CONTROL
CORROSION CONTROL
ALGAE CONTROL
DECHLORINATION CONTROL
TASTE AND ODOR CONTROL
TOOTH DECAY CONTROL
ZEOLITE GENERATION CONTROL
BACTERIA CONTROL
RUST CONTROL
SEWAGE TREATMENT



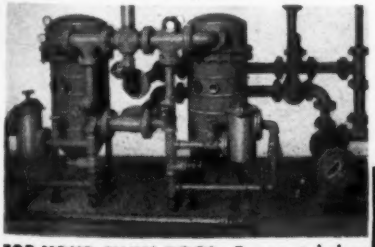
FOR PUMPED WATER SYSTEMS
Constant Rate Feeder — Heavy Duty Midget Chem-O-Feeder. Feeds 0-7½ GPH at 0 to 85 p.s.i.



FOR VARIABLE FLOW SYSTEMS
Flow Proportional Feeder — Automatic and Proportional Chem-O-Feeder. Feeds 0-5 GPH at 4-100 p.s.i.



FOR YOUR CAMP Du-Self — a complete Package Unit—for water treating. For flows up to 25 GPM and 75 p.s.i.



FOR YOUR SWIM POOL For crystal clear swim pool water — Pur-O-Cel Diatomaceous Earth Filter, Duplex Model.

NEW IMPROVED CHEM-O-FEEDER

MODEL 1-47

This new Heavy Duty Chem-O-Feeder has many added features for precision control and easier maintenance. Stroke length is instantly adjustable by turning a knob while pump is operating — a magnifying register glass shows exact reading in thousandths of an inch over a range from 2 to 13 cc per stroke. The new Model 1-47 has convenient oil fill and handy sight gauge — all moving parts operate in an oil bath. Plastic "See-thru" reagent head handles any chemical used in the water works field. Available in simplex, duplex and triplex models. Bulletin SAN-7.

With %Proportioneers% Equipment you can always maintain precision control in water purification and sewage treatment. Ask us for recommendations and quotations. Our experience from over 27,000 installations is at your service.

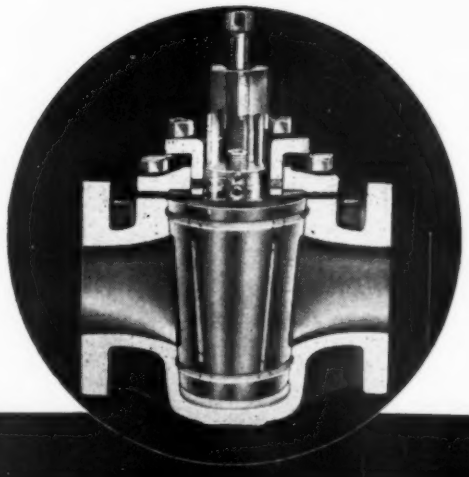
Write for Bulletins.

% PROPORTIONEERS, INC. %

Providence 1, R. I.

Nordstrom valves cost less in terms of service rendered

IN SEWAGE DISPOSAL PLANTS



SEALDPORT..... THE SYSTEM THAT LUBRICATES, SEALS AND JACKS THE PLUG

NORDCOSEAL..... TESTED VALVE LUBRICANTS, COMPOUNDED FOR SPECIFIC SERVICES

TAPERED PLUG..... INSURES PERMANENT, LEAK-PROOF SEATING AT ANY PRESSURE

GUARDED SEAT..... UNEXPOSED TO ABRASIVE OR CORROSIVE MATERIALS IN LINE

ROTARY ACTION..... SIMPLE QUARTER-TURN OPENS OR CLOSES VALVES

STREAMLINED..... SMOOTH-WALLED FLOW PASSAGES

Use only genuine Nordcoseal lubricants

NORDSTROM VALVE DIVISION—*Rockwell Manufacturing Company*
400 North Lexington Avenue, Pittsburgh 8, Pennsylvania

Atlanta, Boston, Chicago, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco, Seattle, Tulsa . . . and leading Supply Houses

Export: Rockwell International Corp., 7701 Empire State Bldg., New York 1

Nordstrom LUBRICATED VALVES

KEEP UPKEEP DOWN

...in Oberlin for example

The municipal water works of Oberlin, Ohio, was the first in the country to use the lime softening process, installing this equipment in 1908. To get the best possible stabilization after softening, an extremely large reservoir for treated water was built, providing, at that time, for 30 days retention, and under present operating conditions for retention from 10 to 20 days. Even with this long retention period, however, there was troublesome after-precipitation of calcium carbonate in service pumps, distribution lines and meters.

In 1939, Threshold Treatment with Calgon was adopted—and the trouble ended. There has been no difficulty with the pumps, and meters have been taken out only for normal repair, *none* due to "freezing up" with lime scale. Precipitation of calcium carbonate in the distribution lines has been virtually non-existent.

Ten years of experience have left the Oberlin authorities well satisfied with the results from Threshold Treatment with Calgon.

Oberlin is only one of many hundred communities of all sizes where Threshold Treatment with Calgon is used to prevent scale, control corrosion, eliminate "red water" or stabilize water following lime softening. These communities have found that they can *depend* on Calgon; they specify Calgon by name—and then make sure that they get Calgon.

Calgon representatives will be glad to discuss the use of Threshold Treatment in your plant.

**T.M. Reg. U.S. Pat. Off.*

HAGAN HALL BUROMIN CALGON

calgon, inc.

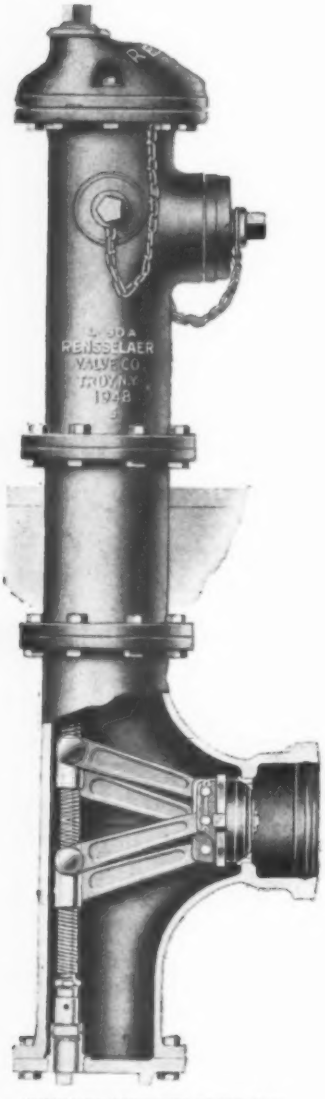
A SUBSIDIARY OF HAGAN CORPORATION

HAGAN BUILDING PITTSBURGH 30, PA.

Just lift it out!

one reason for the LOW MAINTENANCE COST *of the*

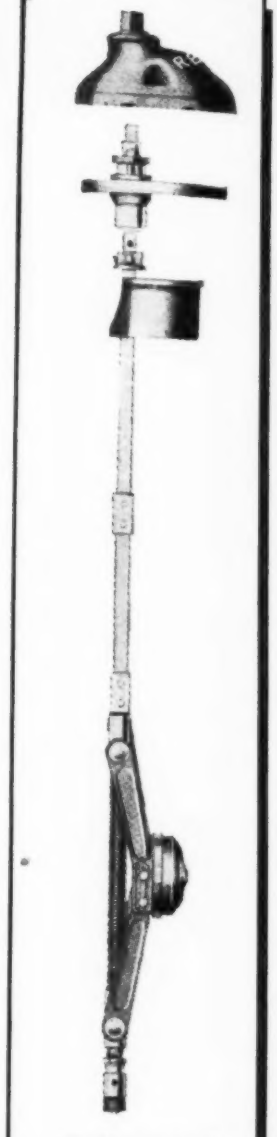
RENSSELAER Corey HYDRANT



HYDRANT CASE CUT AWAY showing steel forgings bearing against case, locking main valve shut

One man, with no special tools or hoist, without digging, by opening valve and removing head, can easily remove and replace all working parts of the RenSSelaer Corey Hydrant. That is only ONE feature which our 65 years of experience have incorporated in this famous Hydrant. NO FLOODING in case of barrel breakage. Main valve MECHANICALLY LOCKED shut by steel forgings bearing against case *(illustrated left)*. No digging to renew broken barrel, thanks to flange at ground line. Hard rubber valve seats will not scar or leak. Drains fast, without clogging. No water hammer. Solid bronze protects long life of vital parts. There's no better investment than RenSSelaer Corey Hydrants . . . thousands in service prove it.

Experienced Field Representatives are at your call to bring you the benefit of RenSSelaer experience in Valves AND Hydrants. Their service puts you under no obligation. Call our nearest office.



Working parts of Corey Hydrant

R1

LEADERSHIP FOR OVER 65 YEARS

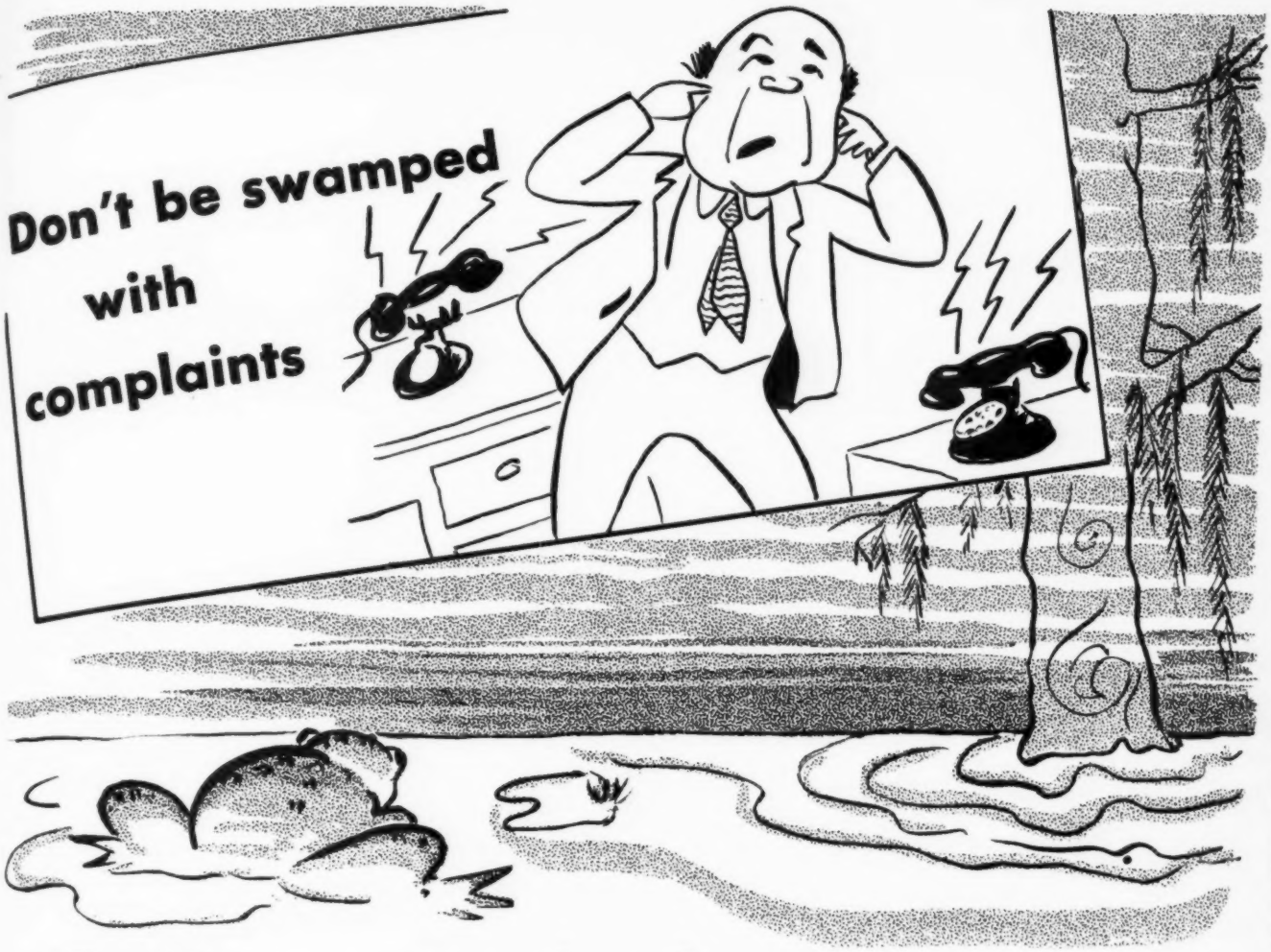
RENSSELAER

Gate Valves • Square Bottom Valves • Tapping Valves and Sleeves
Hydrants • Check Valves • Air Release Valves

RENSSELAER VALVE COMPANY • TROY, N. Y.

Division of Neptune Meter Company

Atlanta, Bala-Cynwyd, Pa., Chicago, Denver, Haverhill, Mass., Hornell, N. Y., Kansas City, Los Angeles, Memphis, Omaha, Pittsburgh, San Francisco, Seattle, Waco



if the water tastes "swampy"

● Be prepared to combat successfully the odorous compounds that will be flushed down to your water intake by high spring waters. Here's what we recommend you do: Run Threshold Odor Tests regularly and stock up with an adequate supply of Aqua Nuchar Activated Carbon. In this way, Aqua Nuchar applications can be started promptly and in high enough dosages to adsorb quickly the intense tastes and odors that develop so suddenly.

To help you when these emergencies arise, stocks of Aqua Nuchar are spotted throughout the country in storage warehouses. Experts from our Technical Service Department are also available to study your taste and odor problems at no cost or obligation.

INSURES PALATABLE NUCHAR DRINKING WATER

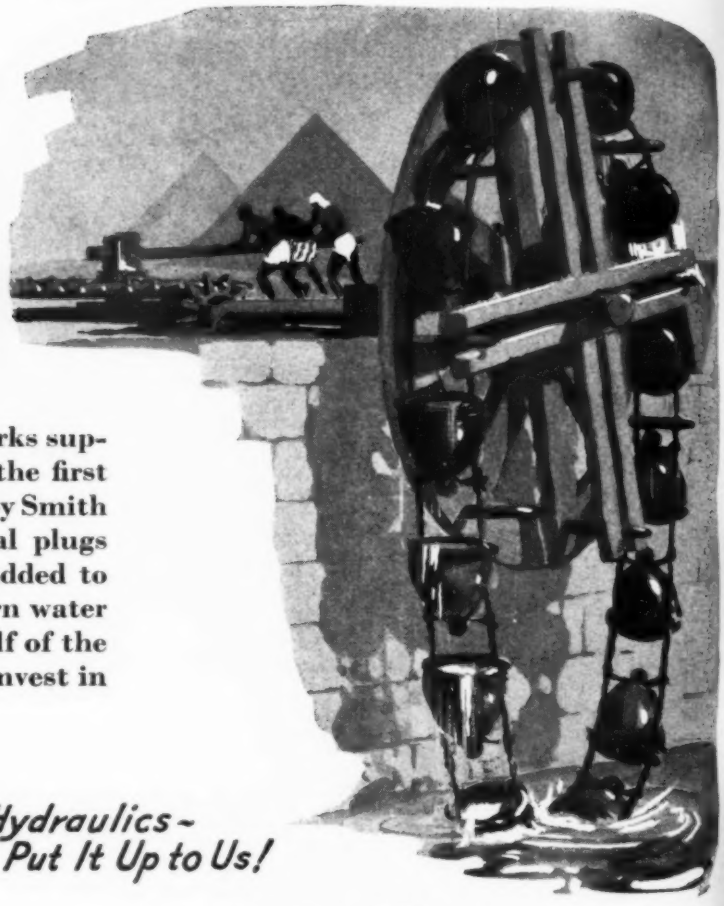
industrial CHEMICAL SALES

division west virginia pulp and paper company

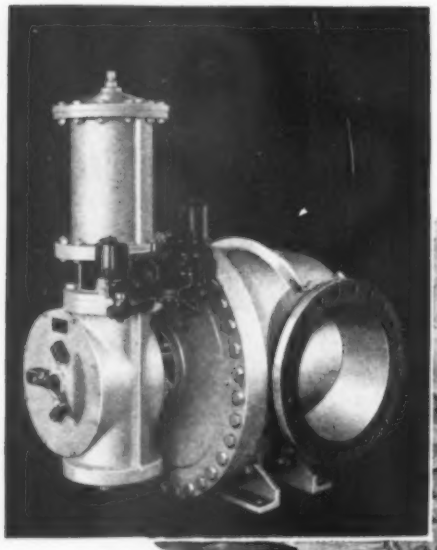
NEW YORK CENTRAL BLDG.	PURE OIL BLDG.	PUBLIC LEDGER BLDG.	LEADER BLDG.
230 PARK AVENUE	35 E. WACKER DRIVE	INDEPENDENCE SQUARE	526 SUPERIOR AVE., N.W.
NEW YORK 17, N. Y.	CHICAGO 1, ILLINOIS	PHILADELPHIA 6, PA.	CLEVELAND 14, OHIO

OTHER PRODUCTS: *Snow Top Precipitated Calcium Carbonate* ● *Nuchar Activated Carbons* ● *Liqro Crude Tall Oil* ● *Indusoil Distilled Tall Oil* *Tallene Tall Oil Pitch* ● *Tallex Abietic Acid* ● *Sulfate Wood Turpentine* ● *Alpha Pinene* ● *Beta Pinene* ● *Polycel Cellulose Fibers* ● *Indulin (lignin)*

Modern WATERWORKS *possible with* Rotovalves *by* SMITH



MOVING ever onward, the huge water works supply systems of today have evolved from the first crude inventions of antiquity! Rotovalves by Smith with their full circular openings, conical plugs and electrically welded seat rings have added to the efficiency and reliability of the modern water works and sewage systems. Assure yourself of the utmost return on your Valve Dollar and invest in Rotovalves. Write for our bulletin.



If It's Hydraulics - Put It Up to Us!

S. MORGAN SMITH Co.

YORK. PENNA. U.S.A.

HERSEY

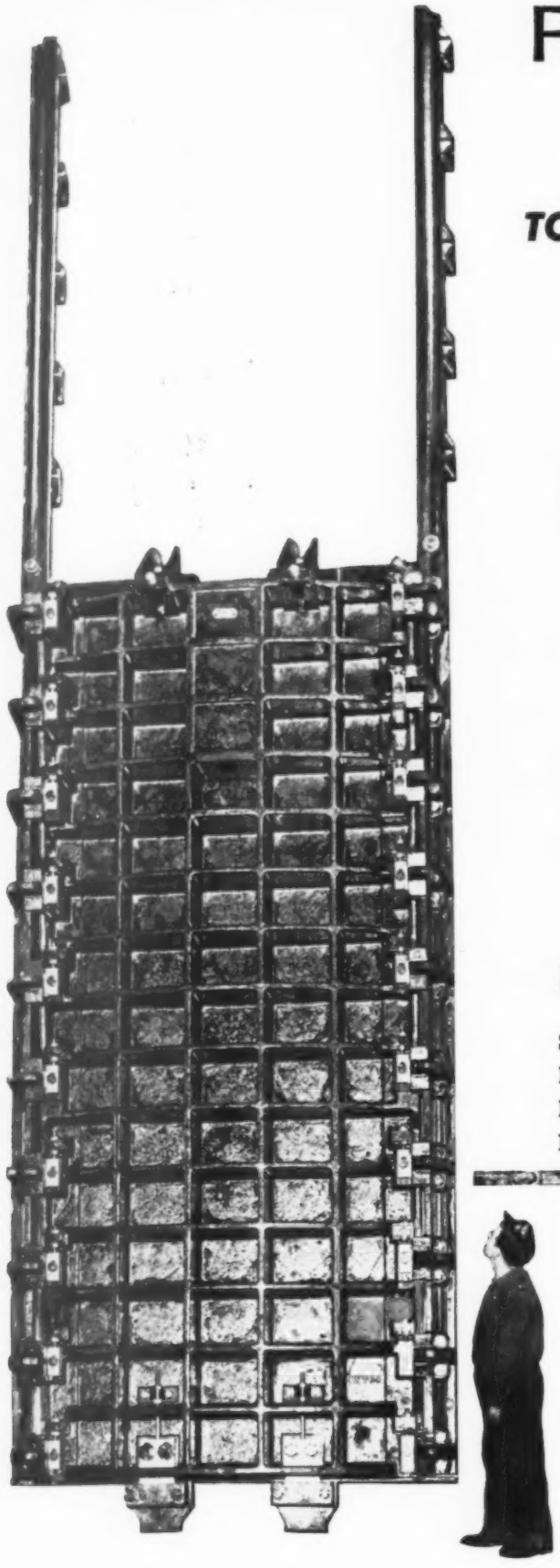
This six-letter word stamped on a Water Meter signifies that you get the best in design, highest percentage of accuracy in registration and the lowest in maintenance cost. You can't go wrong when you specify

HERSEY WATER METERS

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS — CHICAGO
SAN FRANCISCO — LOS ANGELES



FILER & STOWELL SLUICE GATES

TO MEET YOUR REQUIREMENTS

Filer & Stowell Sluice Gates are designed and built to meet any of your requirements.

They are fully bronze mounted; including bronze seats on the frames and discs and adjustable side wedges; also top and bottom wedges when required by operating conditions.

Easily installed and dependable operation at a minimum of cost.

Filer & Stowell Sluice Gates are available in all standard sizes which meet all the usual conditions and special sizes to accommodate unusual conditions. They are available with manual, hydraulic or electric controls.

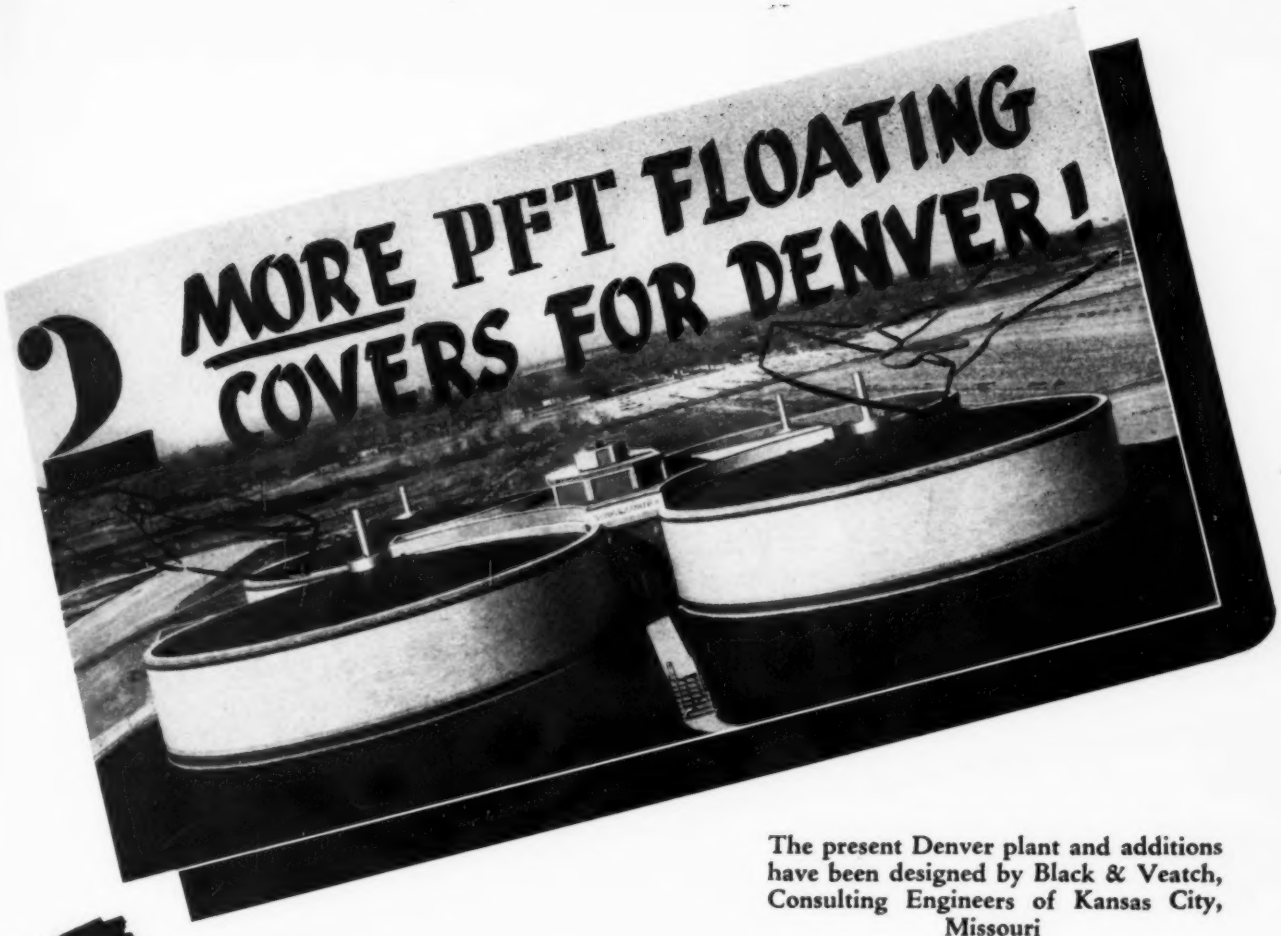
FILER & STOWELL PRODUCTS

Sluice Gates	Gate Valves
Floorstands (Manual)	Fire Hydrants
Floorstands (Electric)	Flap Valves
Hydraulic Cylinders	Special Castings

6 Ft. x 15 Ft. Sluice Gate—One of 46 large Sluice Gates furnished the Board of Water Supply of the City of New York for the Delaware Aqueduct.

THE FILER & STOWELL COMPANY

147 E. BECHER STREET, MILWAUKEE 7, WISCONSIN



The present Denver plant and additions have been designed by Black & Veatch, Consulting Engineers of Kansas City, Missouri

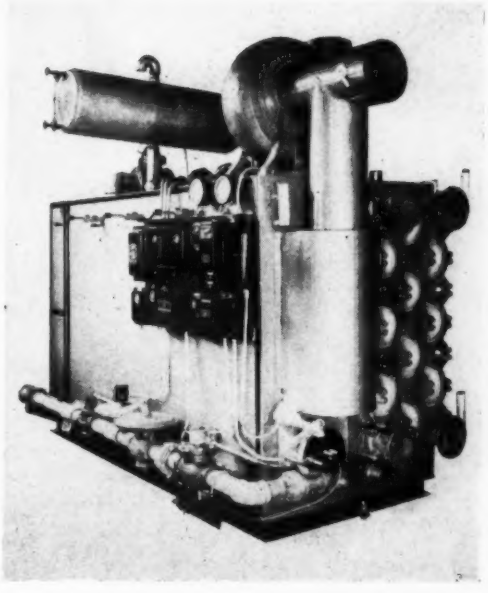
PLUS

3 PFT Digester Heaters and Heat Exchangers!

Supplementing its four 85′ diameter Floating Cover Digesters, fast growing Denver, Colorado is adding two more similar units. When these new units are completed, the six digesters will have a capacity of over 1,000,000 cubic feet.

To assure optimum conditions and maximum operating efficiency of the digesters, three P.F.T. #1000 Digester Heater and Heat Exchangers are being installed. These units will preheat all of the raw sludge before addition to the digesters. Uniform temperatures in all digesters will be maintained by recirculating digester liquor from the various tanks through the new P.F.T. Heaters.

P.F.T. is proud to play a part in providing safe, economical sanitation for the progressive city of Denver. Send for Bulletin 232-P.F.T. Digesters.



One of three PFT #1000 Digester Heaters to be installed at Denver.

P.F.T.

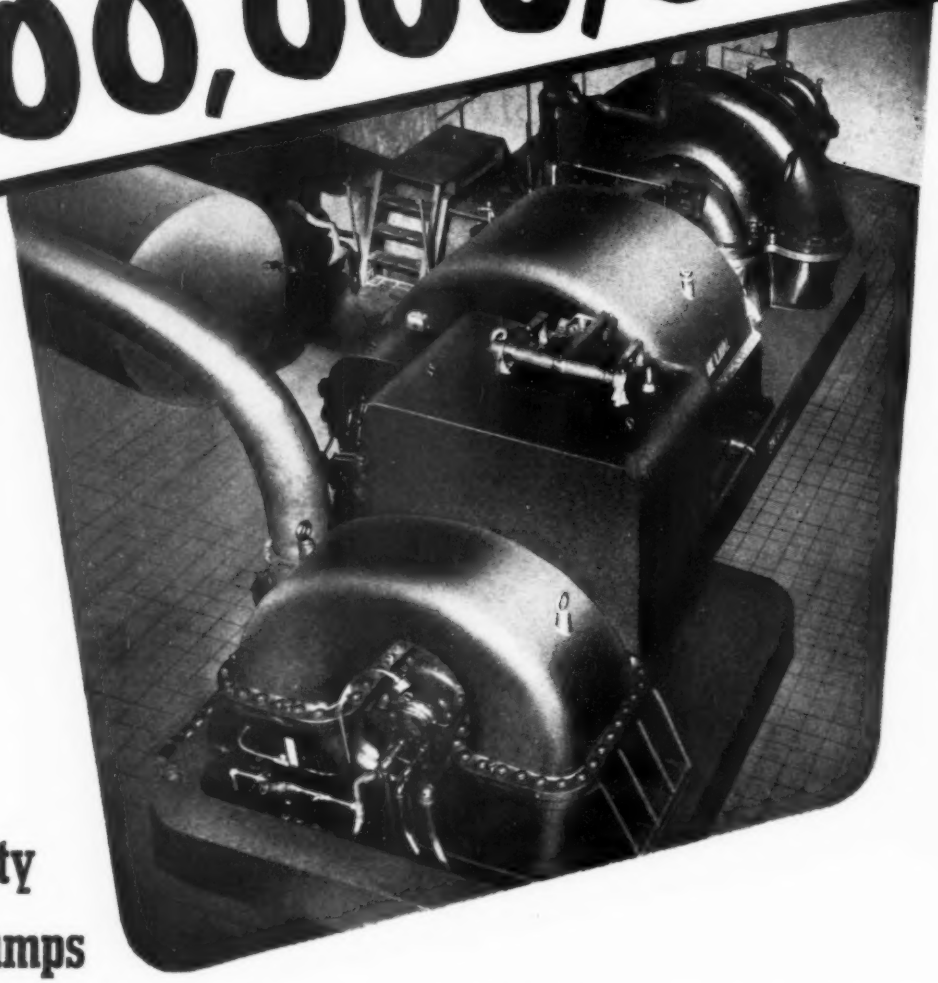
PACIFIC FLUSH TANK CO.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

4241 RAVENSWOOD AVENUE CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • DENVER • TORONTO

1,300,000,000

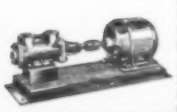


Total Capacity of De Laval Pumps in the City of Chicago . . . 1,300,000,000 Gallons Daily

In the year 1920, the City of Chicago installed its first turbine-driven centrifugal pump—a unit of 60 mgd capacity in the Central Park Station. The performance, trouble-free operation, economy and flexibility of this unit proved to be so satisfactory that additional De Laval turbine-driven pumps were installed in rapid succession.

Today, the City of Chicago is served by a total of 16 De Laval turbine-driven pumps and 5 De Laval motor-driven pumps having a total capacity of one billion, three hundred million gallons daily.

SEND FOR CATALOG 10-WS



DE LAVAL

DE LAVAL STEAM TURBINE CO., TRENTON 2, N.J.

TURBINES • HELICAL GEARS • CENTRIFUGAL BLOWERS AND COMPRESSORS
CENTRIFUGAL PUMPS • WORM GEAR SPEED REDUCERS • IMO OIL PUMPS

WW7

Philadelphia finds the Answer

FOR BETTER WATER—WITH *Ozone!*

Installation of the world's largest Ozone plant is Philadelphia's answer to overcoming taste and odor problems in water drawn from *surface supplies.* This is one of the first major steps in this city's progressive, long-range water improvement program.

This new Ozone installation in the Belmont Filtration plant in Philadelphia currently treats about 36,000,000 gallons daily with an ultimate capacity of 70,000,000 gallons a day. It was designed, built and installed by The Welsbach Corporation after two years' of extensive tests demonstrated the efficiency and effectiveness of the Ozone process in producing high quality drinking water . . . pleasant in taste and odorless . . . at reasonable costs.

Do you have a taste, odor or color problem in your water supply system?

Philadelphia's answer through the Welsbach Ozone Process can be your answer, too!

Write today for the Philadelphia story on Ozonation at the world's largest Ozonation plant. The booklet, "Philadelphia Finds the Answer," will be gladly sent you.

THE WELSBACH CORPORATION
OZONE PROCESSES DIVISION

1500 Walnut Street
Philadelphia 2, Pa.

TRADE DARLING MARK

HYDRANTS

...many types and sizes but only one high standard of performance!

Standard, one-piece barrel

Quikfix, breakable coupling type

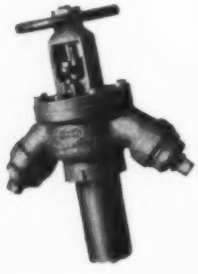
Flange above ground-line type

With outside independent hose nozzle valves

Tee-base type

Water crane type

Flush type



Tropical type

YES, there's a Darling hydrant that's just right for practically every known requirement. A few of the different types are shown here. All have one thing in common . . . performance at its efficient, low-cost best!

Here's a point to bear in mind. The basic design features that pay off so well in Darling-equipped towns, are applied to all but one of the various Darling types. Many of the working parts are interchangeable . . . planned that way for the sake of user economy, simplified maintenance and low inventory.

Do you have locations where frequent traffic damage is the rule? Are there other places where concealed flush-type hydrants would be ideal? Perhaps there are points where Darling's practical Tee-base type can save you money. And how about future fills and grade changes?

Why not let a Darling engineer explain how effectively, how *economically* your particular service conditions can be met with modern Darling hydrants? Or, if you prefer, we'll gladly send you Catalog 17M. It describes all the various features, types and sizes in complete detail.

TRADE DARLING MARK

DARLING VALVE & MANUFACTURING CO.

Williamsport 11, Pa.

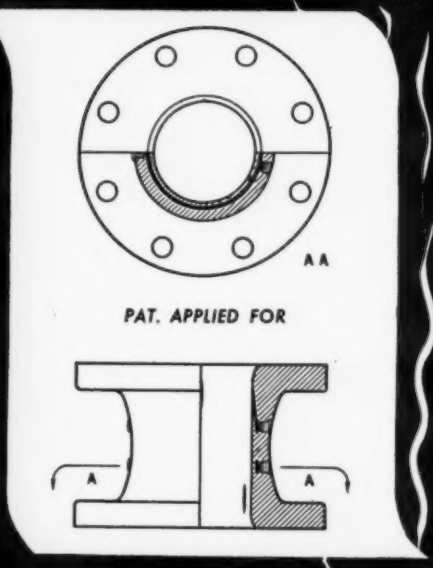
NEW BETHLEHEM FLOW TUBE

(Gentile Patents)

NO STRAIGHT RUN LIMITATIONS
NEGLIGIBLE RESISTANCE TO FLOW

A constant coefficient over 8:1 range of discharge, higher accuracy, more economy, greater range—these are some of the advantages of the new BETHLEHEM FLOW TUBE. Tested by one of the nation's leading hydraulic laboratories, it consists essentially of a short, straight length of pipe equipped with two groups of pressure nozzles around the inner periphery—one group pointing upstream, the other downstream. The nozzle groups are interconnected by common pressure rings from which connections are made to the high and low pressure sides, respectively, of a standard flow meter.

To measure fluid flow rate with greater accuracy . . . more economy . . . investigate this new primary element now! Write for your copy of the folder, "Bethlehem Flow Tube," today.



BETHLEHEM FOUNDRY

& MACHINE COMPANY • BETHLEHEM • PENNA.

IOWA manufactures a complete line of valves
for sewage treatment plants
Specify IOWA VALVES and let us solve your problems
on sewage flow control

IOWA VALVE COMPANY

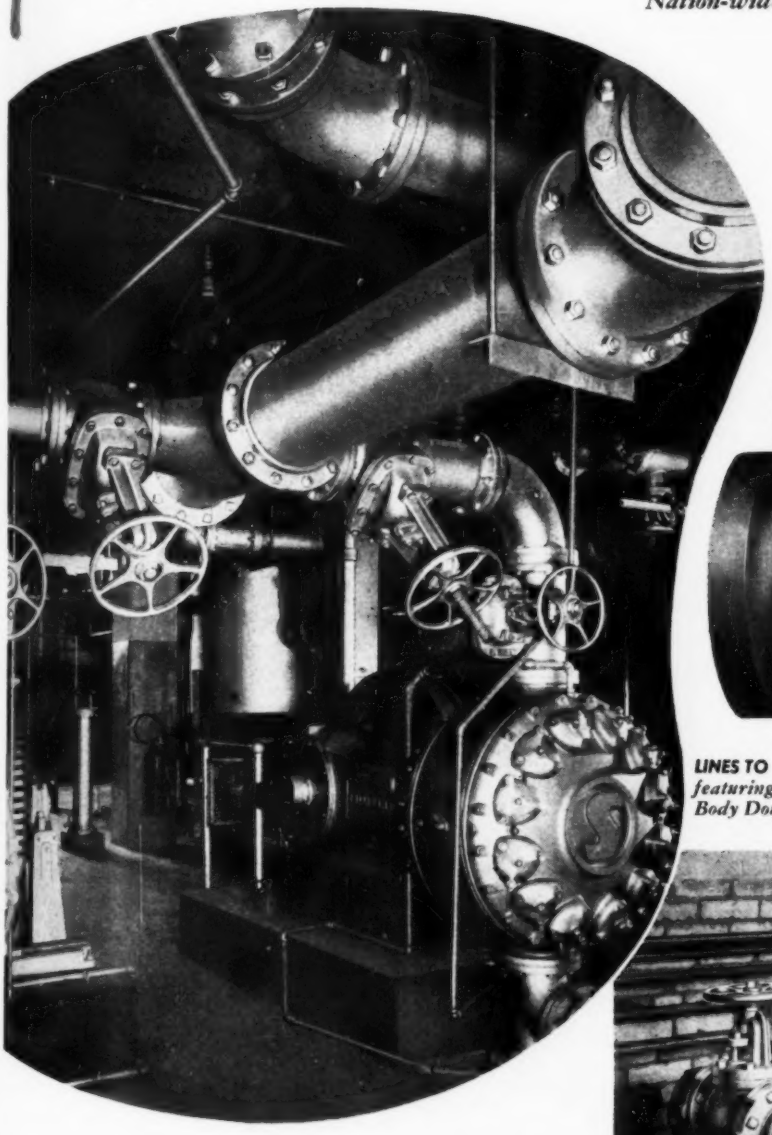
201-299 N. Talman Ave., Chicago 80, Ill. • *A Subsidiary of James B. Clow & Sons*

you rate valves by *performance* too

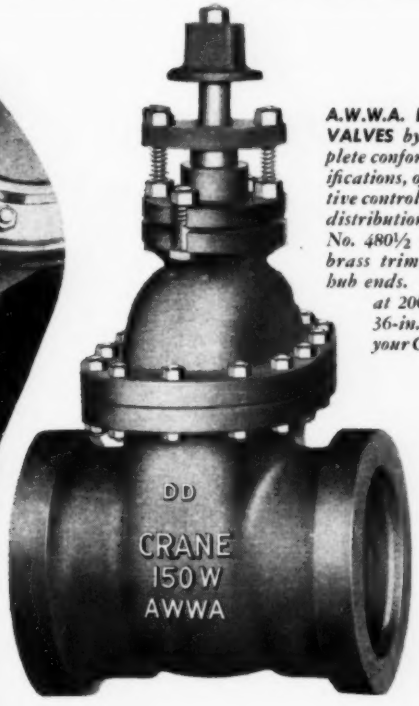
That's why you find Crane valves rated so highly by men who manage and maintain public water systems. They know that although valves may look alike, it's performance that counts. And that you get dependable performance at low cost when your system is protected by Crane valves.

In fittings as in valves, Crane Quality . . . both in materials and workmanship . . . can play a big part in helping to maintain your utilities at peak efficiency. For today, as always, Crane materials give outstanding service under all operating conditions . . . help to minimize repair and replacement expense.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Nation-wide Service Through Branches and Wholesalers

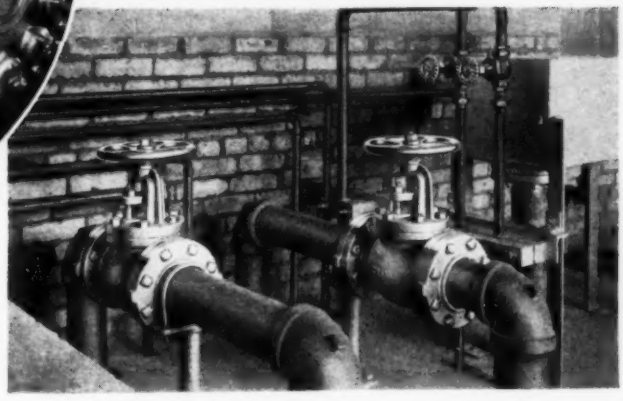


AIR LINES IN SEWAGE *and industrial waste disposal plant using Crane 125-pound Iron Body Globe Valves and screwed fittings. One order to Crane covers all piping equipment for installations of this type.*



A.W.W.A. DOUBLE DISC GATE VALVES *by Crane assure complete conformance to latest specifications, offer smooth and positive control for water mains and distribution lines. Shown here, No. 480½ iron body gate with brass trim. Non-rising stem; hub ends. Sizes to 12-in. rated at 200 pounds; sizes 14 to 36-in., at 150 pounds. See your Crane Catalog, p. 126.*

LINES TO VACUUM PUMPS *in disposal plant, featuring Crane 200-pound flanged Iron Body Double Disc Gate Valves and fittings.*



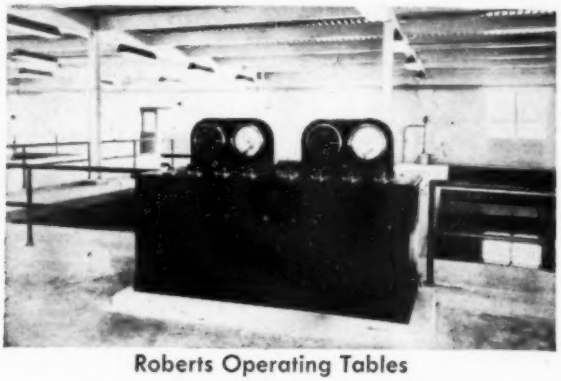
VALVES · FITTINGS · PIPE

CRANE

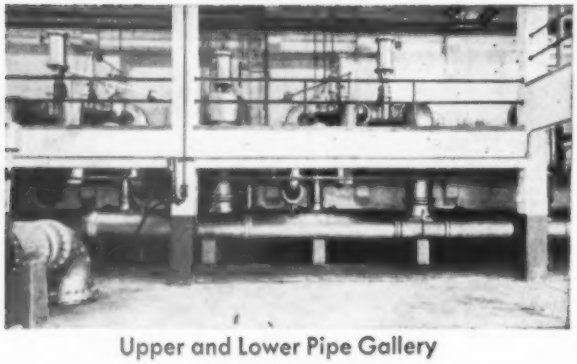
PLUMBING AND HEATING

New 40 m.g.d. Filter Plant at the City of Savannah, Georgia.
Consulting Engineers:—J. E. Sirrine Company
General Contractors:—Virginia Engineering Company

AGAIN it's ROBERTS FILTER SAVANNAH, GEORGIA



Roberts Operating Tables



Upper and Lower Pipe Gallery

Compact Pipe Gallery
Made Possible by Roberts Waste Valves

View of Operating Floor

MECHANICAL EQUIPMENT BY ROBERTS FILTER MFG. CO. DARBY, PENNA.

ROBERTS FILTER MANUFACTURING CO.
607 COLUMBIA AVENUE • DARBY, PENNA.

Save...

Time, Money and Labor in making pipe joints

... The only field equipment necessary to make a Universal Cast Iron Pipe Bolted Joint is a Ratchet Wrench.

by using

UNIVERSAL*
CAST IRON PIPE

(PIPE and JOINT are ONE)

Outstanding Advantages:

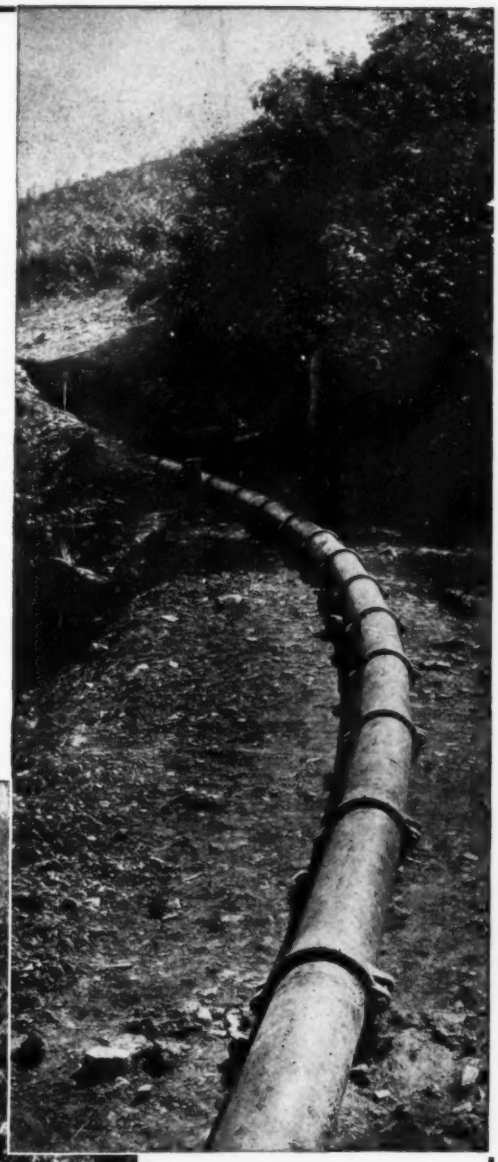
1. *No calking or pouring of lead or lead substitutes. No gaskets used.*
2. No bell holes to dig. Can be laid in a narrow trench. Cost of wide trenching is eliminated.
3. *Can be laid with SPEED. Easier and cheaper to install because only two bolts need to be inserted in the lugs, tightened with a ratchet wrench (the only tool needed), and the completed joint is made in a few minutes. Experienced workmen are not needed.*
4. Nothing to deteriorate; nothing to work loose; no leakage; no maintenance cost.
5. Flexibility: Universal pipe is very flexible. It withstands expansion, contraction, unequal settlement, vibration and shock, and electrolysis. Many curves are laid with straight lengths and do not need special fittings.
6. *Universal pipe can be laid on rocky soil, under water and in sub-zero weather.*

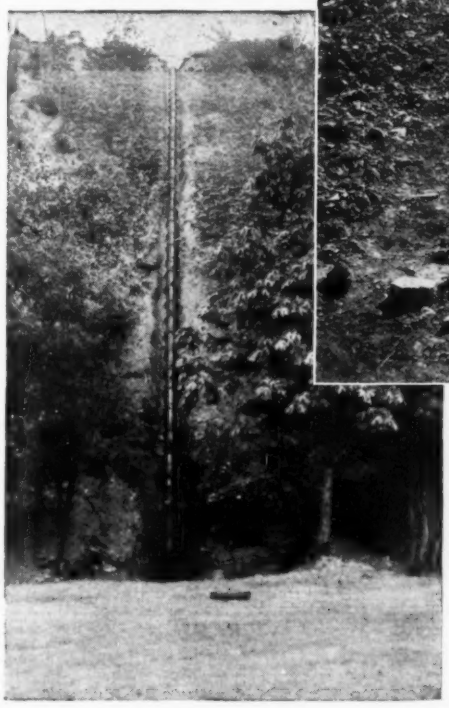
Specify UNIVERSAL PIPE for water mains and sewers

Furnished in hot tar dipped, cement lined, and enameline lining.

THE CENTRAL FOUNDRY CO.
386 FOURTH AVENUE, NEW YORK 16

*Reg. U.S. Pat. Off.





Above *All straight lengths of Universal pipe in this curve.*

At left *16" pipe laid on a 45-Degree slope. Note deflection at top to level ground without fittings.*

USE THE COUPON

DEPT. D

THE CENTRAL FOUNDRY COMPANY
386 Fourth Avenue, New York 16

I am interested in SAVING LABOR, TIME, MONEY and EQUIPMENT in pipe-laying. Send me the UNIVERSAL catalog.

Name .....

Position .....

Address .....

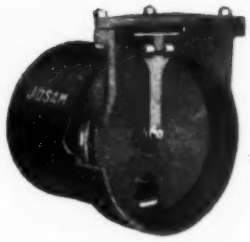
.....

LASTING PROTECTION *for* PIPE LINES!

SERIES NO. 1170

JOSAM BACKWATER SEWER VALVES

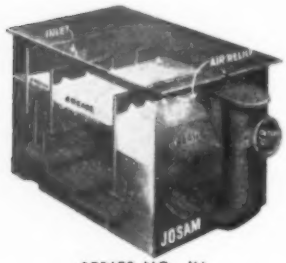
Drain lines and sewers frequently are unable to cope with drainage load. When that condition occurs, all connecting lines fill and all low levels—basement, areaways, pits, tunnels, etc., flood, with resulting damage to property, equipment and foundations. In the Josam Backwater Sewer Valve the flap closes tightly with slightest backflow, preventing entry of any backwater or sewage through the drain lines. Supersensitive side-swing flap opens wide to permit full water way up to size of pipe for which it was designed.



SERIES NO. 1110½

JOSAM BACKWATER VALVES FOR TERMINAL SERVICE

When placed at the discharge end of sewer lines, the Josam Sewer Terminal Valve is a safeguard against sewage backflow. Applicable in a sewer at a manhole or as a sluice, river or tidewater outlet, between settling basins in sewage disposal plants. Valve mechanism is identical in design, construction and operation with full backwater valve, and the body is the inlet half of the full valve.



SERIES NO. JN

JOSAM GREASE INTERCEPTORS

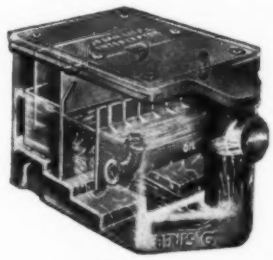
The Josam Cascade Grease Interceptor provides maximum grease interception and retention for all types of installations. Grease is removed from waste water before it clogs drain lines. Made in types and sizes for any requirement. Equipped with flow control to insure maximum grease retention efficiency.

SERIES NO. 1470

JOSAM SHOCK ABSORBERS

For Water Hammer in Pipe Lines

Modern water supply systems everywhere are subjected to the water hammer. Loosened hangers, failure of joints, valves and connections, and similar breakdowns may be evidence that destrutive water hammer is at work destroying your water supply system. The Josam Shock Absorber is widely used to quiet the nerve wracking noise and danger of water hammer wherever water and other liquids are distributed under pressure through pipe lines.



SERIES NO. G

JOSAM OIL INTERCEPTORS

Oil, gasoline, naphtha and similar volatile liquids may cause fire, explosion and water pollution if allowed to accumulate in the drainage system. With a Josam Oil Interceptor located at the proper point, the dangerous liquids are eliminated from the waste water and safely drawn off. Made in a wide range of types and sizes.

World's Largest Manufacturer of Plumbing Drainage Products

For Complete Information and Literature—MAIL COUPON TODAY

JOSAM MANUFACTURING COMPANY

General Offices: 320 Josam Bldg., Cleveland 13, Ohio
Manufacturing Division: Michigan City, Indiana

Josam STANDARD OF THE WORLD

JOSAM-PACIFIC CO.
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JOSAM MANUFACTURING COMPANY
320 Josam Bldg., Cleveland 13, Ohio

Please send literature on the following:

- ☐ Drains
- ☐ Backwater Valves
- ☐ Interceptors
- ☐ Swimming Pools
- ☐ Shock Absorbers
- ☐ Manual R covering all Products

Name .....

Title .....

Address .....

City ..... Zone ..... State .....

CUTS PIPE HANDLING COST 50%

. . . Says a Wisconsin City

BUCYRUS ERIE
HYDROCRANE

ON a pipe laying job for the Water and Sewage Utility of a Wisconsin City in the 15,000 population class, a Bucyrus-Erie Hydrocrane moved 5400 feet of 16-inch water pipe from freight car to trench in 28 working days — with only four workers. The superintendent wrote:

> "We are positive that use of the Crane reduced our handling and installation costs at least 50 percent, in addition to speeding up the project and reducing the amount of man power and equipment required. . . . This unit is invaluable for our type of work."

Here's what the fast-working, truck-mounted Hydrocrane did:

1. Unloaded pipe from railroad cars
2. Stockpiled pipe in city yard
3. Loaded pipe on trailers
4. Hauled trailers to job site
5. Distributed pipe along the trench
6. Lowered pipe into trench and held it in place for workers to set.

The Hydrocrane did all these jobs quickly, smoothly, easily despite the fact that each pipe length weighed between 1700 and 1800 pounds.

Every working function of the Hydrocrane is fully hydraulic. Control is so precise the operator can lower pipe a fraction of an inch at a time — an important safety factor. The Hydrocrane can also be used for many digging, erection and material handling jobs. Clamshell bucket closes hydraulically — gets big loads even in hard material.

Hydrocranes are available in two sizes — 2-ton ¼ yard Model H-2 and the 3-ton ⅜ yard Model H-3. For further information on this time and money-saving unit, fill out the coupon and mail today.

BUCYRUS-ERIE HYDROCRANE DIVISION
SOUTH MILWAUKEE, WISCONSIN

Gentlemen: I want the full story on the Hydrocrane.

Name.....

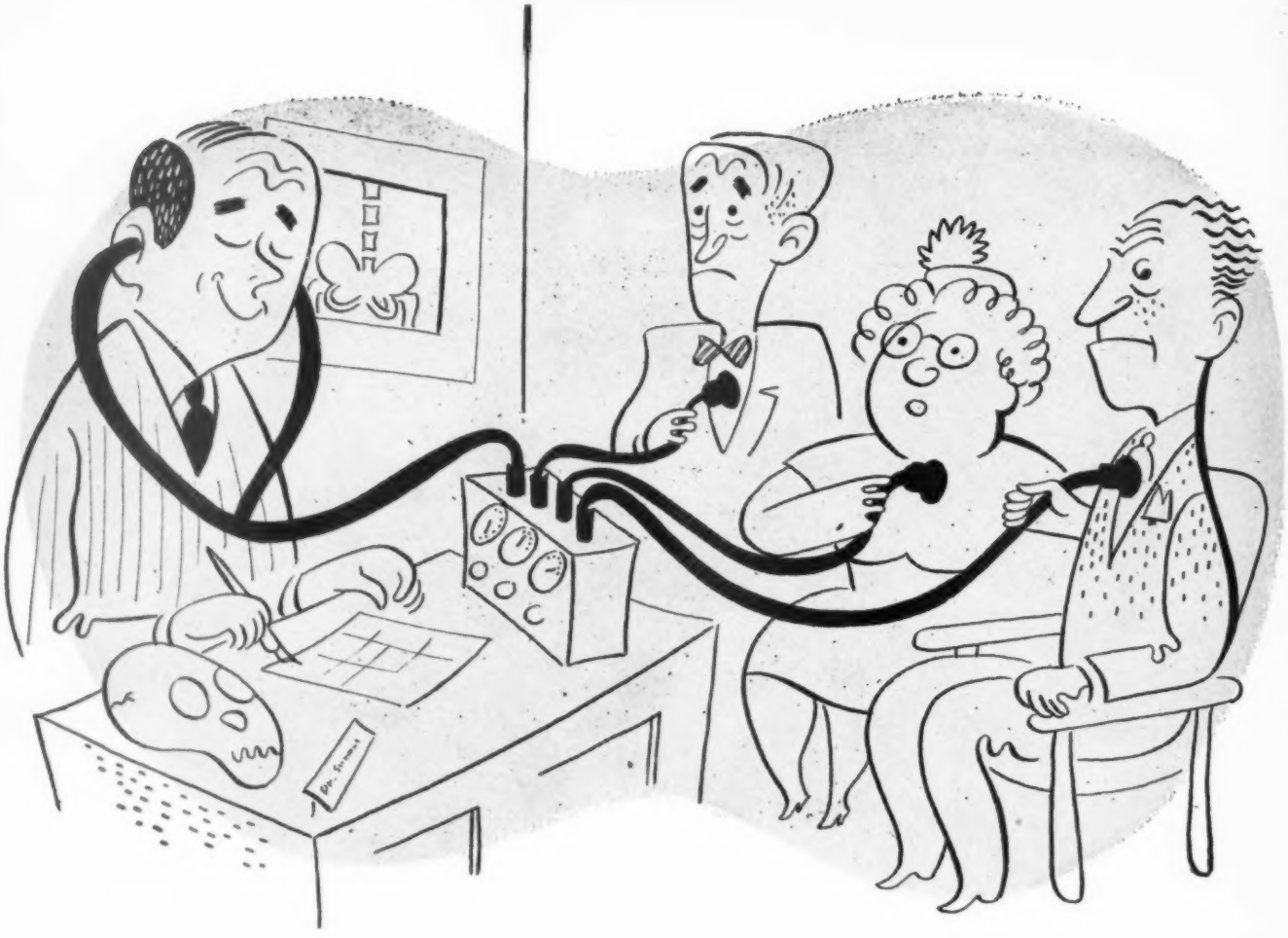
Dept. or Company.....

Address.....

City..... State.....

23H49

BUCYRUS-ERIE HYDROCRANE DIVISION
SOUTH MILWAUKEE, WISCONSIN



Reduced Treatment Costs

Less load at the disposal plant—and, therefore, a reduction in sewage treatment costs—is one of the practical advantages that often result from the use of Transite* Sewer Pipe.

There are two good reasons for this:

(1) Transite's special sleeve-type joints that cut sewer line infiltration to a minimum.

(2) Transite's long 13-foot lengths that reduce the number of joints in the line—an additional safeguard against infiltration.

Besides the immediate saving in treatment costs, this reduction in load also enables plant capacity to be conserved for future needs. And, where new treatment facilities are planned, it permits consideration of a smaller plant . . . with possible important economies in disposal equipment.

Other Transite Economies . . . Transite has an exceptionally smooth interior that reduces resistance to flow. This, combined with its long lengths that help maintain uniform grades, plus fewer joints that reduce turbulence, often permits designing the system with flatter grades and shallower trenches. Or, as an alternate economy, pipe of smaller diameter may be specified.

Transite Sewer Pipe is made of asbestos, cement and silica by a special method of manufacture which develops high, uniform strength and resistance to corrosion. It is available in four strength classes in sizes to 36". This permits selection of the pipe best suited to trench conditions, frequently eliminates the need for concrete cradles.

For further details, write Johns-Manville, Box 290, New York 16, N. Y.

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INFILCO'S new TYPE E4 Feeder brings a new, high degree of *sustained* accuracy and efficiency to the feeding of dry chemicals. It represents more than 25 years of constant development and perfection . . 25 years of *experience* in the design and manufacture of Chemical Feeding Equipment for water purification and sewage or waste treatment operations. You can expect the "E4" to feed many millions of pounds of chemicals with *unvarying accuracy* and a minimum of upkeep cost. Adjusting the feed rate is a quick, easy job. Simple, sturdy and compact, this *better* Feeder will give dependable, *dust-free* service for years. Made for either constant rate or automatic proportional feed operation. May we send you complete information?

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This portable "Limitorque" is equipped with the famous *torque-limiting feature* (which operates in both Opening and Closing directions); *The limit switch* which may be set for any desired travel (automatic re-setting); *A Universal Joint connection* is also provided for compensation of misalignment between floorstand and power unit.

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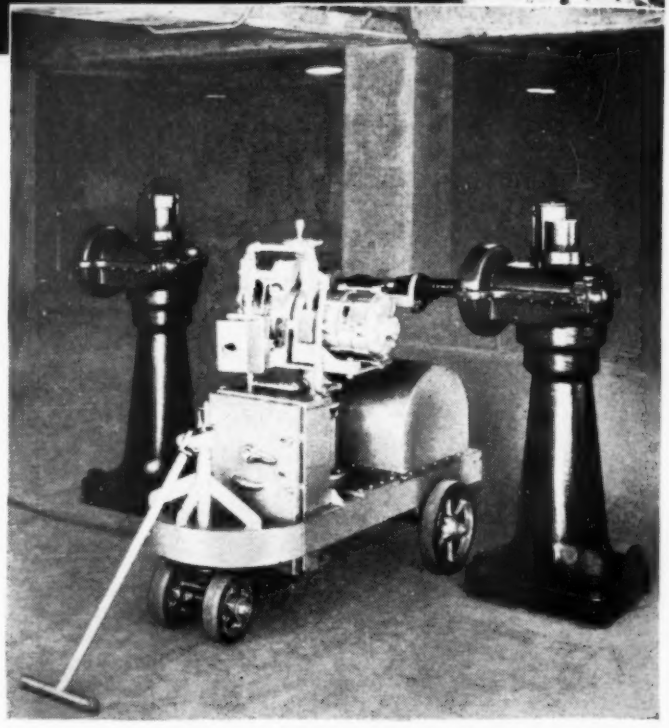

The *Portable "Limitorque"* shown directly above was built to the exacting specifications of the Filtration Division Engineers, City of Chicago, Ill. The photo at the top of the page shows a general view of the Filtration Plant taken from South Breakwater Light. (All photos courtesy of South District Filtration Plant at Chicago, Ill.).

Send for 96 page "Limitorque" Catalog and please use your Business Letterhead when requesting same.

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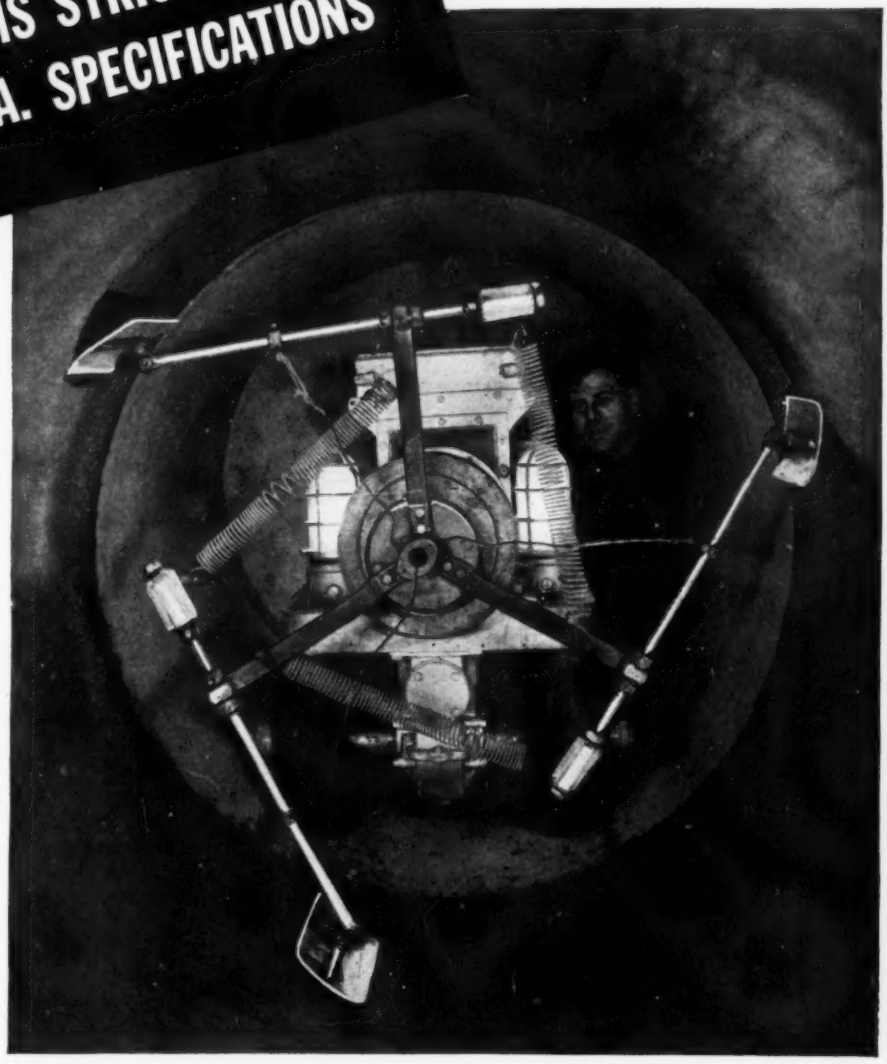

▶▶▶▶ The Standard Specifications for cement-mortar protective coatings issued by the American Water Works Association provide: "Interior of the entire line, including both curves and tangents, shall be by centrifugal machine . . . the machine shall apply the mortar by centrifugal action without the use of compressed air and follow its application by automatic trowelling to a uniform thickness and smooth finished surface."

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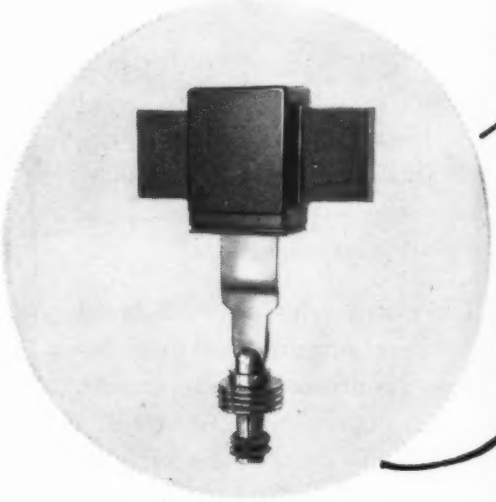
in one functional package

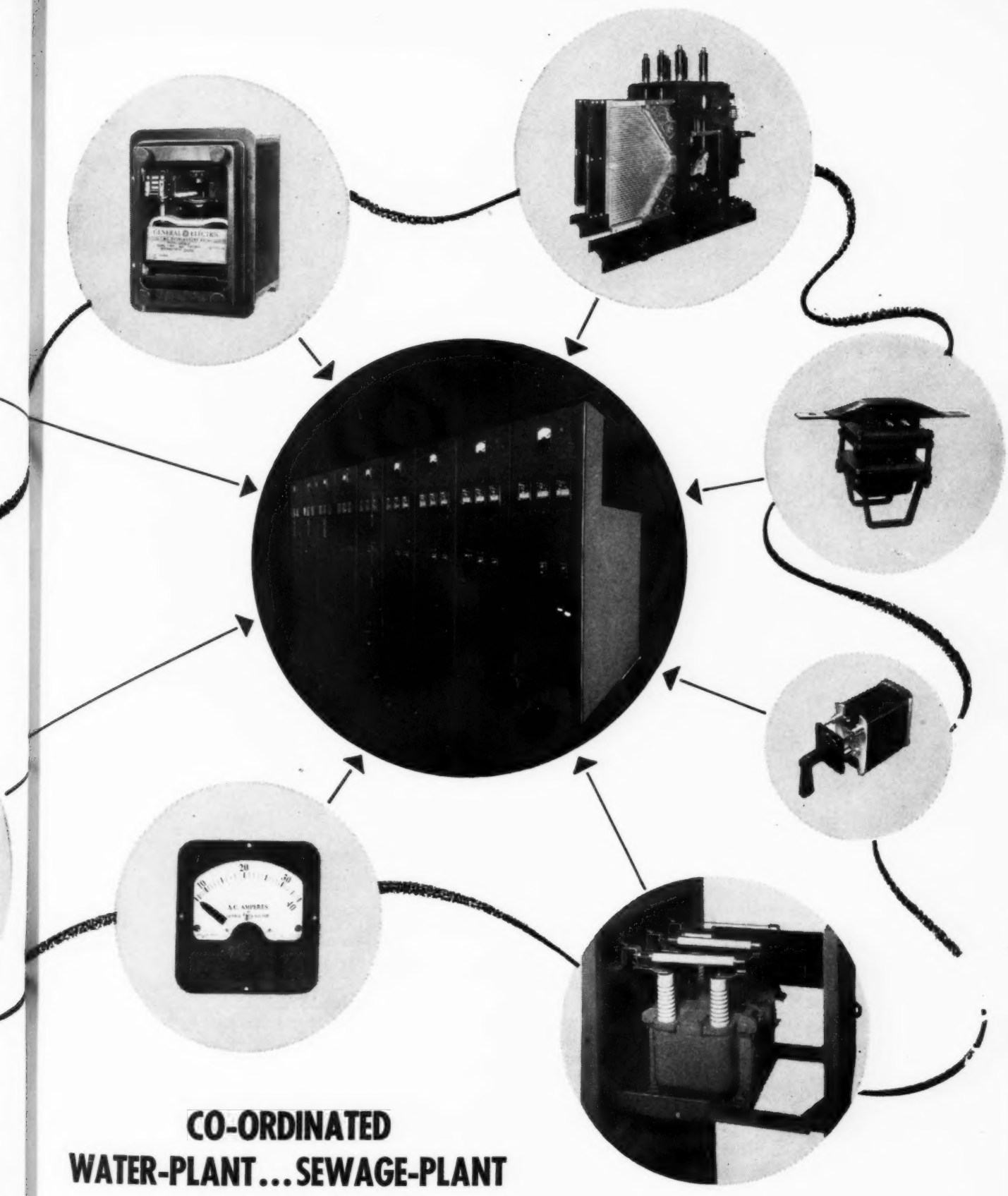
G-E metal-enclosed switchgear designed, factory-assembled and tested to solve all your protection, metering and relaying problems

A simple, one-line diagram is all the information our water and sewage engineers need to go to work on your power-distribution problem in new or expanding plants. From this diagram they can help you plan your distribution system and the necessary switchgear control and protective equipments to provide efficient flow of power to your load areas. These equipments will include circuit breakers of adequate interrupting capacity, relay protection, instrumentation and other associated devices, assembled and interconnected within streamline metal enclosures.



More Information?

Your consulting engineer or General Electric representative will tell you more about these equipments and help you plan your entire electrical layout. Consult him early, so that you can profit by co-ordinated planning and thereby simplify engineering, construction and installation. *Apparatus Dept., General Electric Company, Schenectady, N. Y.*



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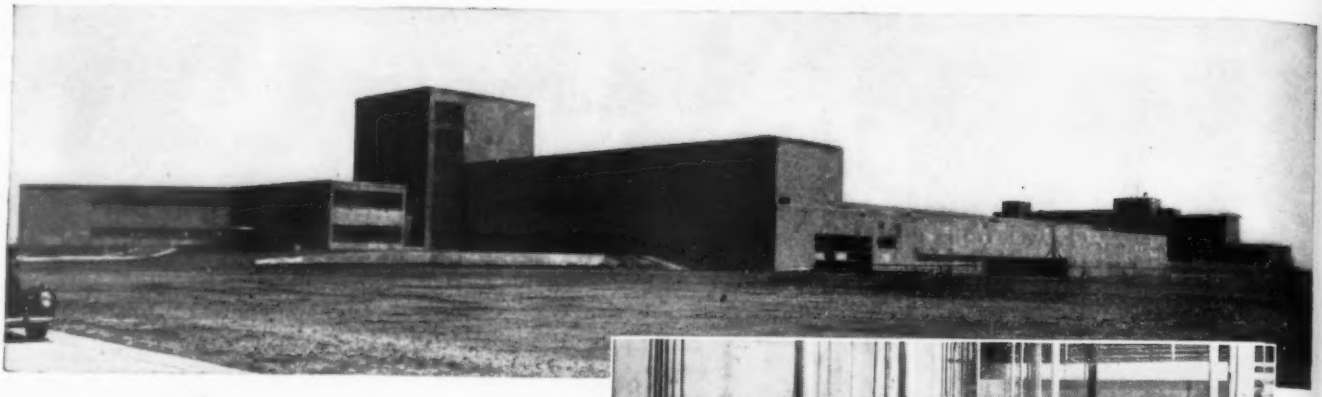
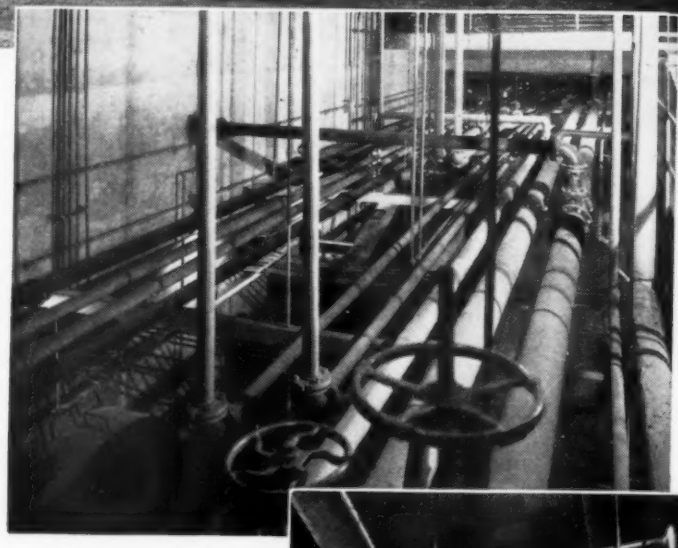


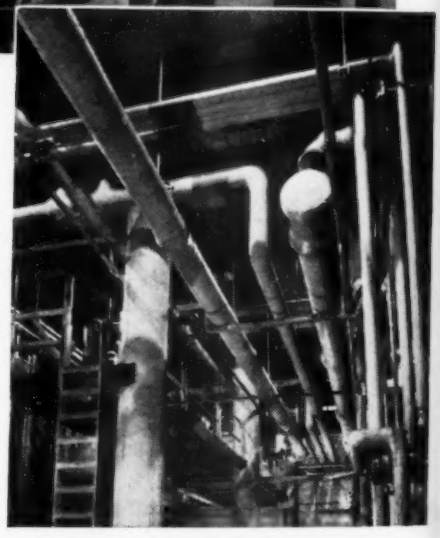


THIS $25,000,000

FILTRATION PLANT PROJECT

filters out corrosion hazards with

BYERS WROUGHT IRON PIPE



In three additional units in a $25,000,000 filtration plant project, started before the war and designed to supply Chicago's rapidly expanding South Side, the designers aimed at maximum life with minimum maintenance. All hot and cold water lines, and all heating lines, in the Chemical Building and the Administration Building are Byers Wrought Iron pipe, installed by W. T. Maloney Co., Plumbing Contractor, and M. J. Corboy Co. and Robert Gordon Co., Heating Contractors. Wrought iron was also used in certain aqua ammonia, flushing and sampling lines. Consulting Engineers on this project are Greely and Hansen, and Alvord, Burdick, and Howson. The design and supervision of construction was done by the engineers in the Department of Public Works, Chicago, Ill.

The importance of selecting the most durable material is obvious with today's cost of maintenance so high. And the ability of wrought iron to withstand the conditions encountered is obvious, because of the remarkable service records it has made in many of Chicago's oldest buildings. For example—a survey conducted in the area revealed wrought iron water lines *still serving* after periods of from 44 to 81 years. The average life to date for 10 installations was 46.9 years. In contrast, a study of 10 buildings in which ordinary piping materials had been used showed an average life *to failure* of 20.2 years.

The reason wrought iron endures in punishing applications is found in the unique structure and composition of the material. Tiny threads of glass-like silicate slag, 200,000 to 250,000 per square inch of section, are distributed through the body of high-purity iron. These threads halt and disperse corrosive attack, discouraging the local pitting that causes vulnerable materials to fail prematurely.

Our bulletin, "WROUGHT IRON FOR PIPING SYSTEMS", will give you some helpful information, that should save you money in maintaining your piping installations. Ask for a copy.

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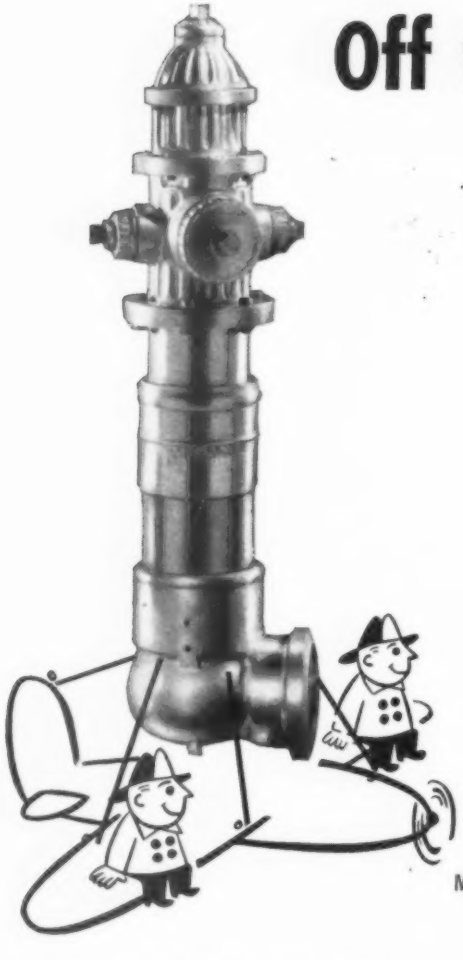

WESTWARD AGAIN for R. D. Wood people and the Mathews Modernized Hydrant; but this time it is Chicago.

As at past A.W.W.A. conferences, we will have a full-scale working model of the hydrant on display. Many of the delegates are probably familiar with this product; and so far as they are concerned much of our time no doubt will be given over to meeting old friends and discussing matters of common interest. We look forward to it with great pleasure.

As for those of you who have never seen the Mathews, we hope to meet every one of you, too. Stop by and let us show you why it is so often said that cities protected by Mathews Modernized Hydrants are the safest.

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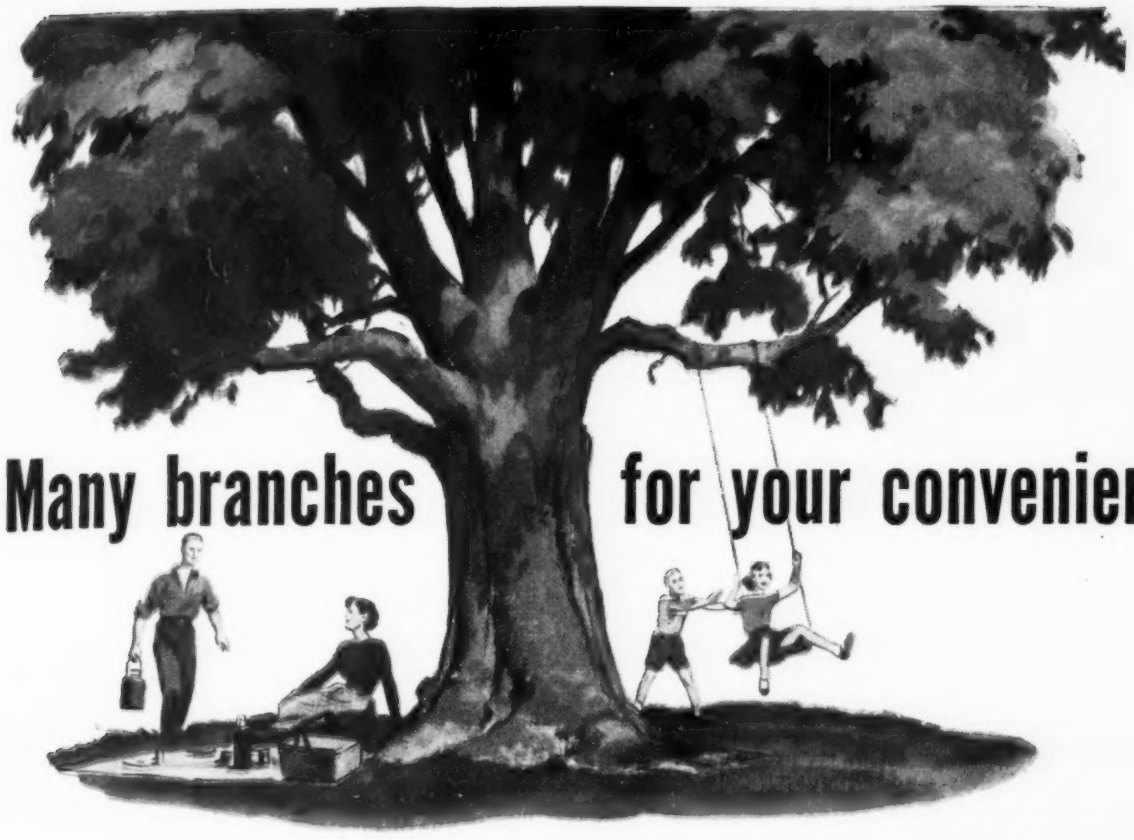

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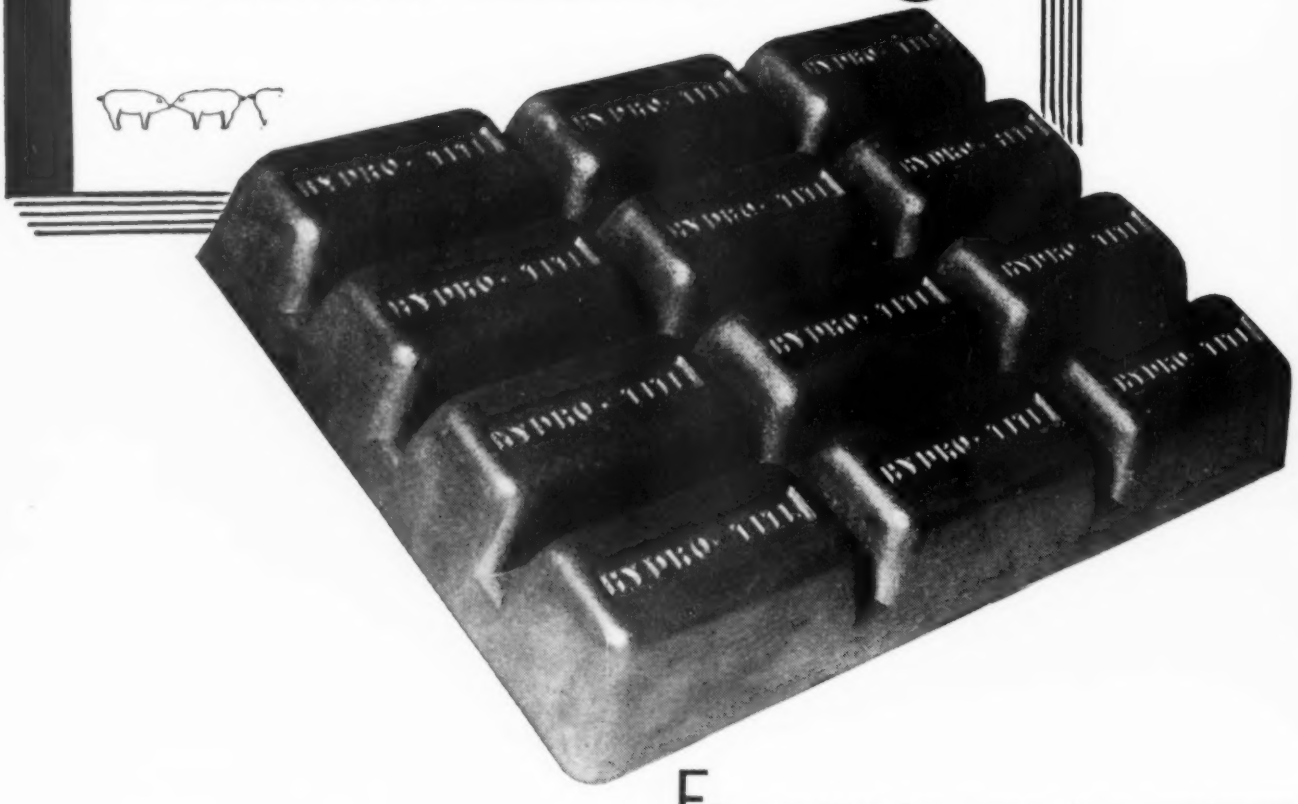

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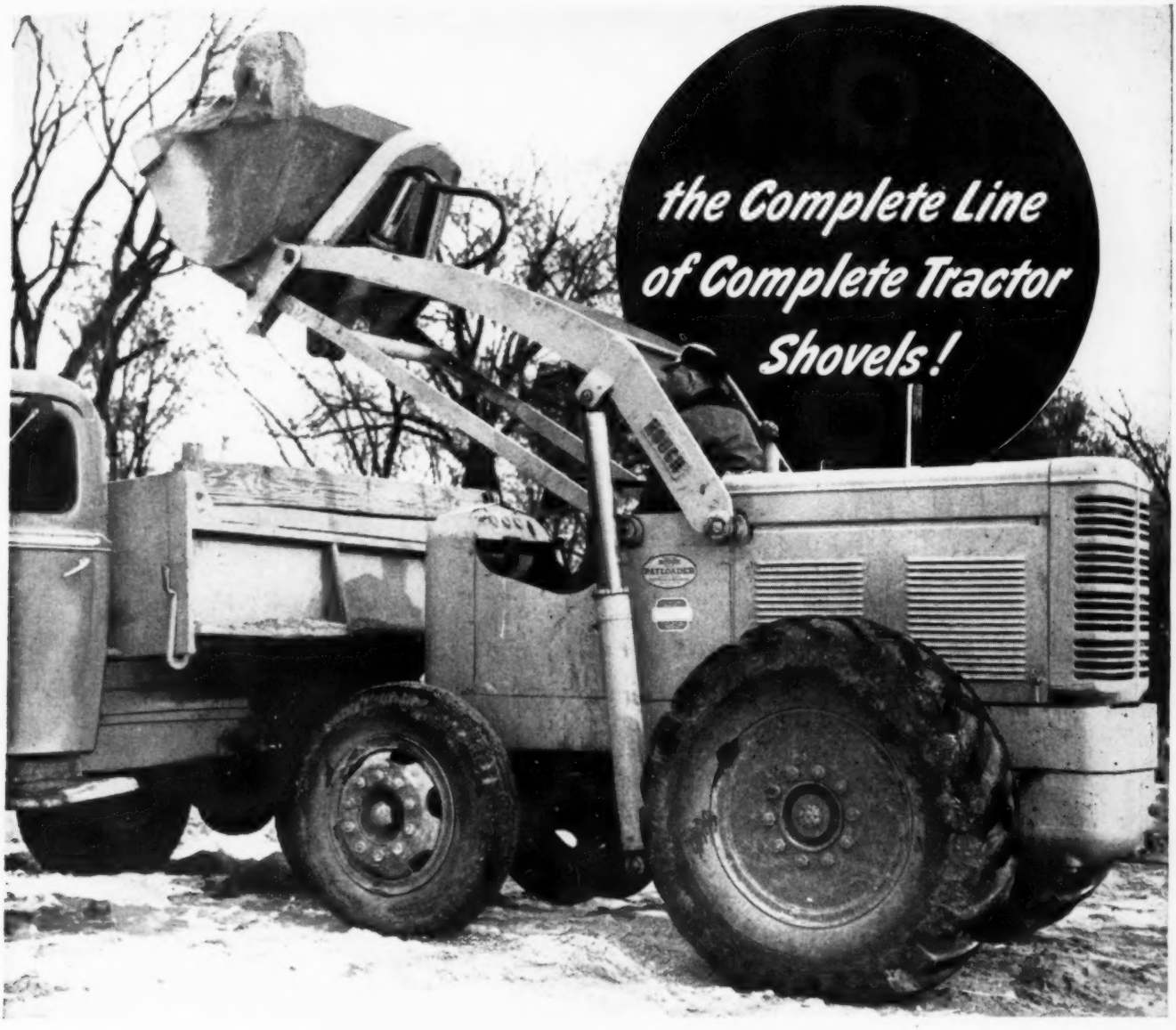

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SEND for FREE LITERATURE on any of the four sizes of PAY-LOADERS: the 10½ cu. ft. Model HA, the ¾ yd. Model HF, the 1¼ yd. Model HL or the 1½ yd., 4-wheel drive Model HM.

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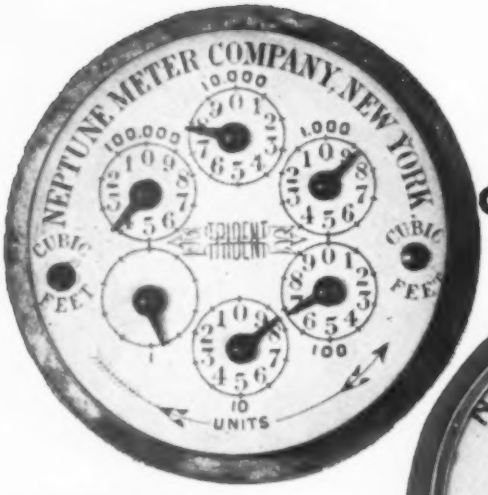

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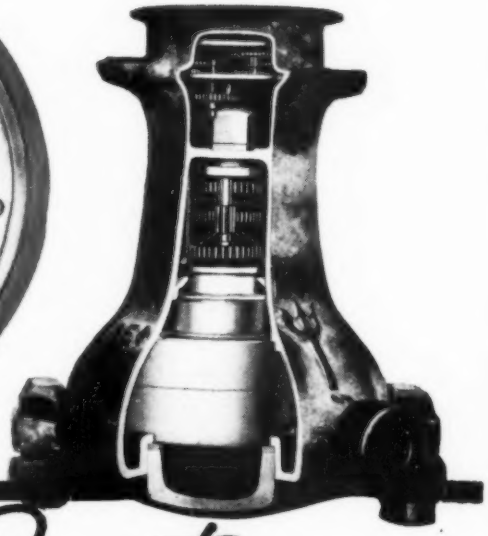

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ECONOMY IN INVENTORY — THROUGH TRIDENT

Interchangeability

WATER & SEWAGE WORKS

VOL. 96, NO. 5 MAY, 1949

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Chief Filtration Chemist

and

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Engr. of Water Purification

DEPT. OF PUBLIC WORKS
CHICAGO, ILL.

THIS article will describe the chlorination equipment and chlorination control as practiced at Chicago's South District Filtration Plant. The lake water at times is highly polluted with industrial wastes and some sewage, and often has high chlorine absorption. The equipment must be adequate for the high chlorine dosages required, and the control must be such that frequent and rapid changes in the chlorine demand can be met with no lessening of the residual chlorine to be maintained in the finished water. In addition to the equipment for applying chlorine to the water, equipment is provided for recording residual chlorine automatically on charts. Laboratory residual tests are also made at frequent intervals on samples of water collected at several points in the filtration plant to give assurance that chlorination is adequate. Transmission of chlorine solutions considerable distances for post-chlorination or emergency by-pass chlorination is another feature of the system.

CHLORINATING EQUIPMENT

Unloading and Storage

The equipment for unloading, storing and feeding chlorine into the water is shown in Figs. 1, 2 and 3. The chlorine is received in one-ton containers on multiple tank railroad cars, each holding 15 containers. The containers are unloaded with an electric hoist supported on a monorail that extends over the car and the storage platform. The empty containers are also stored on the same platform. Figs. 2 and 3 show a car in position for unloading. Each car is reloaded with empty containers before returning to the manufacturer. The shipments are scheduled so that 15 containers are empty by the time a loaded car arrives. Ninety containers, full and empty, are at the plant all of the time. The storage platform, monorail and hoist are shown in Fig. 1.

Scale Room

Figs. 2, 3 and 6 show the scale room. Eight scales have been installed and there is room for two additional scales. A steel tank is mounted on

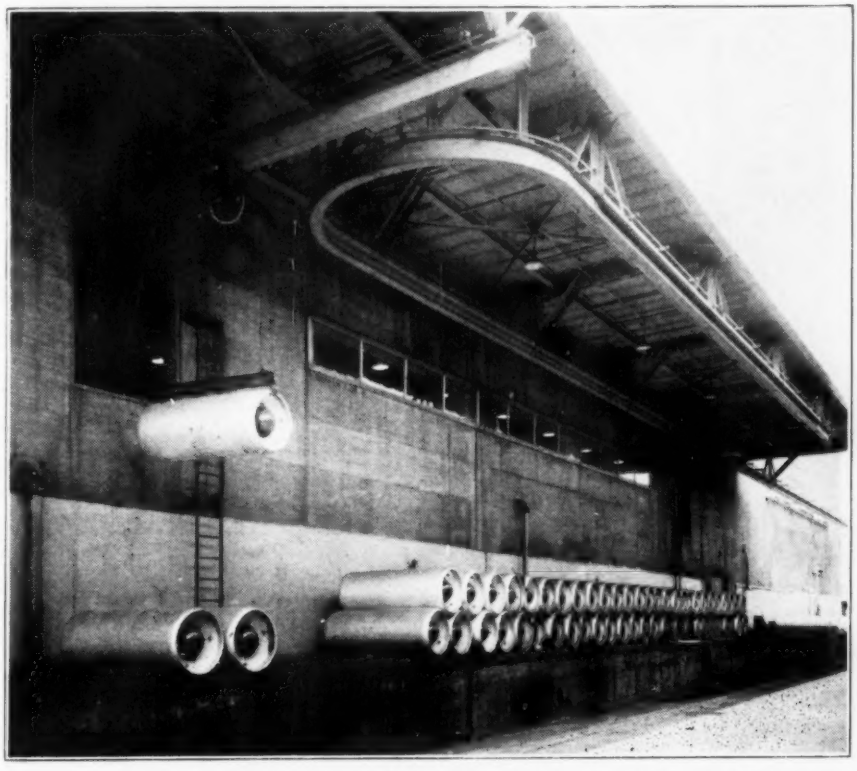


Fig. 1—Ton-Container Unloading and Handling Equipment and Storage Platform.
Full containers in at Lower Door; Empties out at Near Door.—See Sketch, Fig. 2.

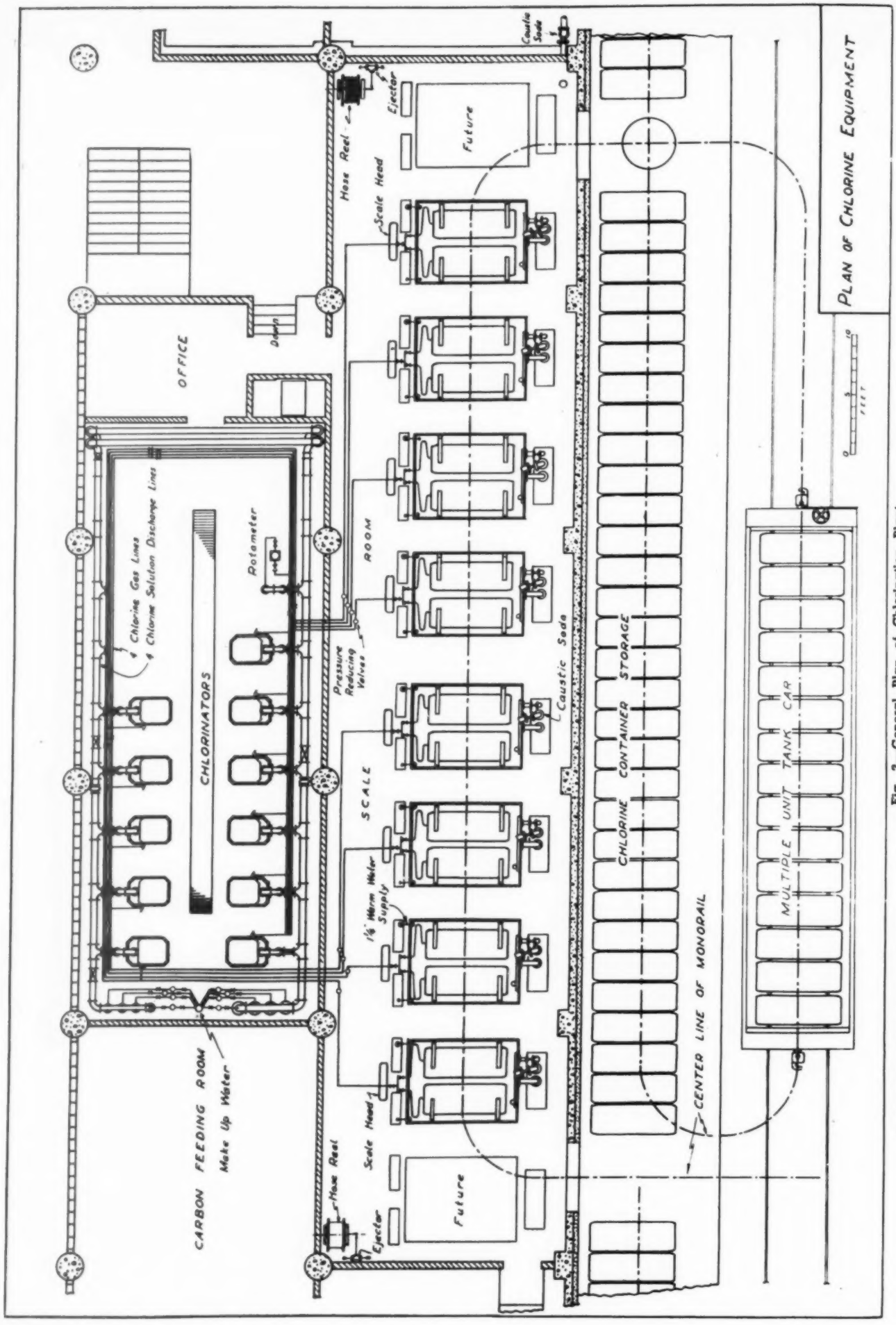


Fig. 2—General Plan of Chlorination Plant
Full containers in Center; Empties on Left and Right. Note Locations of the Important Pressure Reducing Valves on Chlorine Gas Lines.

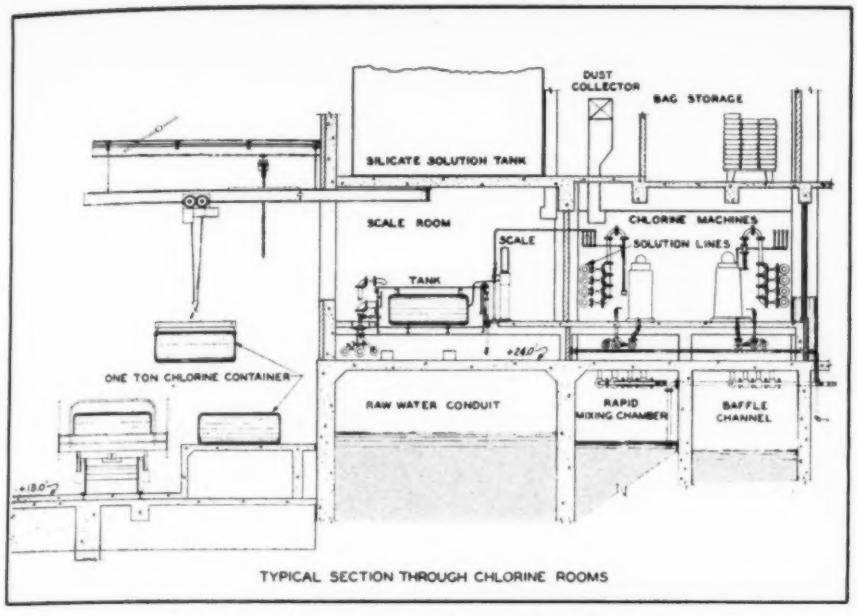


Fig. 3—Section Through Chlorination Plant

each scale, and two-ton containers are placed in each tank. The main use of the tanks is to pass slightly warmed water around the containers to hasten evaporation of chlorine from liquid to gas, especially during times when there is considerable use of chlorine. The temperature of the water bath is maintained at approximately 70° F. by recirculating the bath water through a heater by means of small centrifugal pumps. Another planned use of the scale tanks is to absorb the chlorine from a leaky container by flooding the tank with concentrated caustic soda solution from a storage tank located on the floor above. This would be used only in case the chlorine leak is so large that it cannot be handled by other means. Swinging clamps are provided in each scale tank to clamp the containers down and prevent them from floating in the scale tank should it be flooded with caustic soda. So far it has not been necessary to use the caustic soda during the 3½ years that the plant has been in operation.

Scales

Eight 7.5 ton Toledo scales, each with a dial capacity of 5,000 lbs., have been installed. Automatic recording of weight by printing the weight on a tape at intervals is provided.

Gas Piping

Flexible copper tubes, ⅜ in. in dia., connect the containers to eight manifolds, one manifold for each scale. There are two ½ in. chlorine valves fastened to the container side of each of the manifolds. The piping from the manifolds to the chlorinators is ¾ in. extra heavy wrought iron pipe. Four headers of ¾ in. pipe extend almost around the chlorinator room as shown in Fig. 2, with four of the scale assemblies connected to one end of the line and four connected near the other end. Each chlorinator is connected to all four header lines. In this way one or more scale assemblies can be connected to any of the chlorinators. Each of the eight scale assemblies could be used to feed to eight separate points of chlorine application simultaneously. So far, there never has been occasion to use this number at one time.

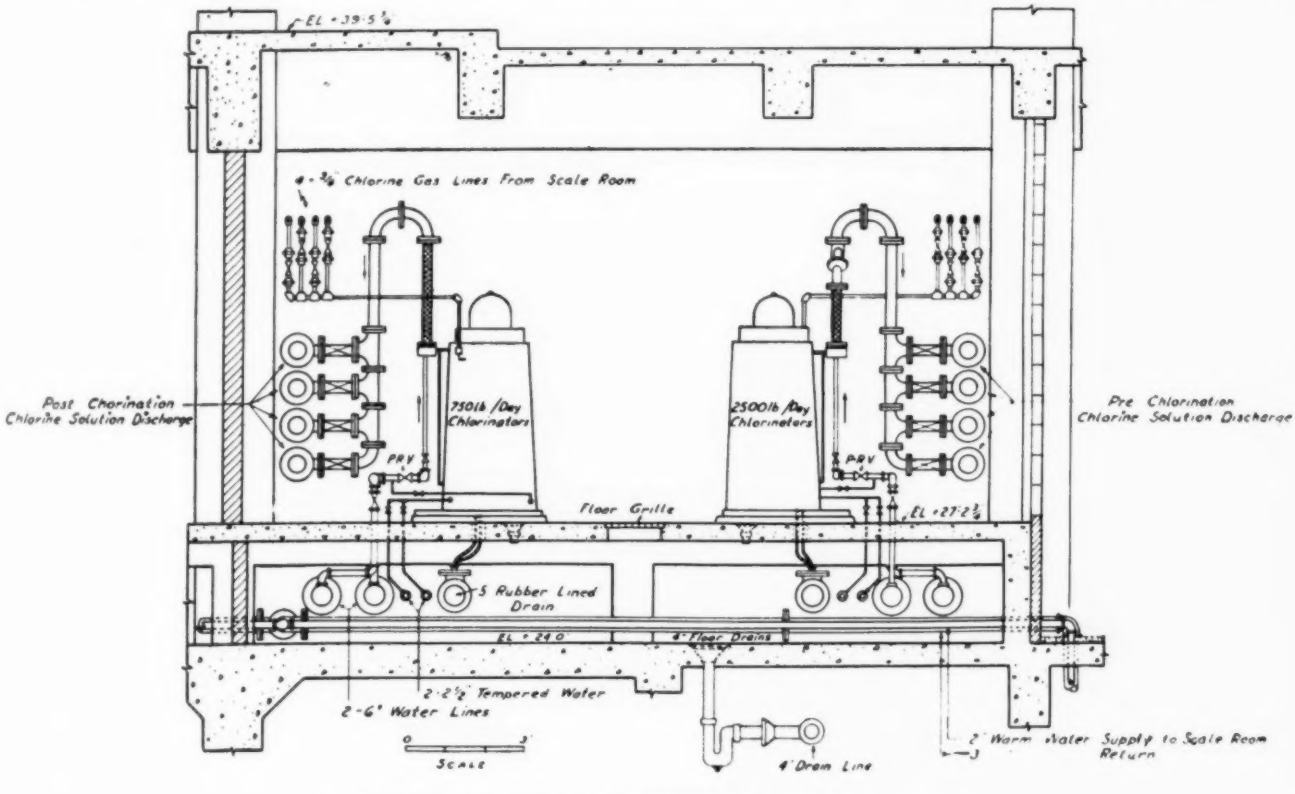


Fig. 4—Section Through Chlorinator Room Showing Details

Note Floor Grille and Ducts for Evacuating Room of Chlorine Gas in Case of Leakage.

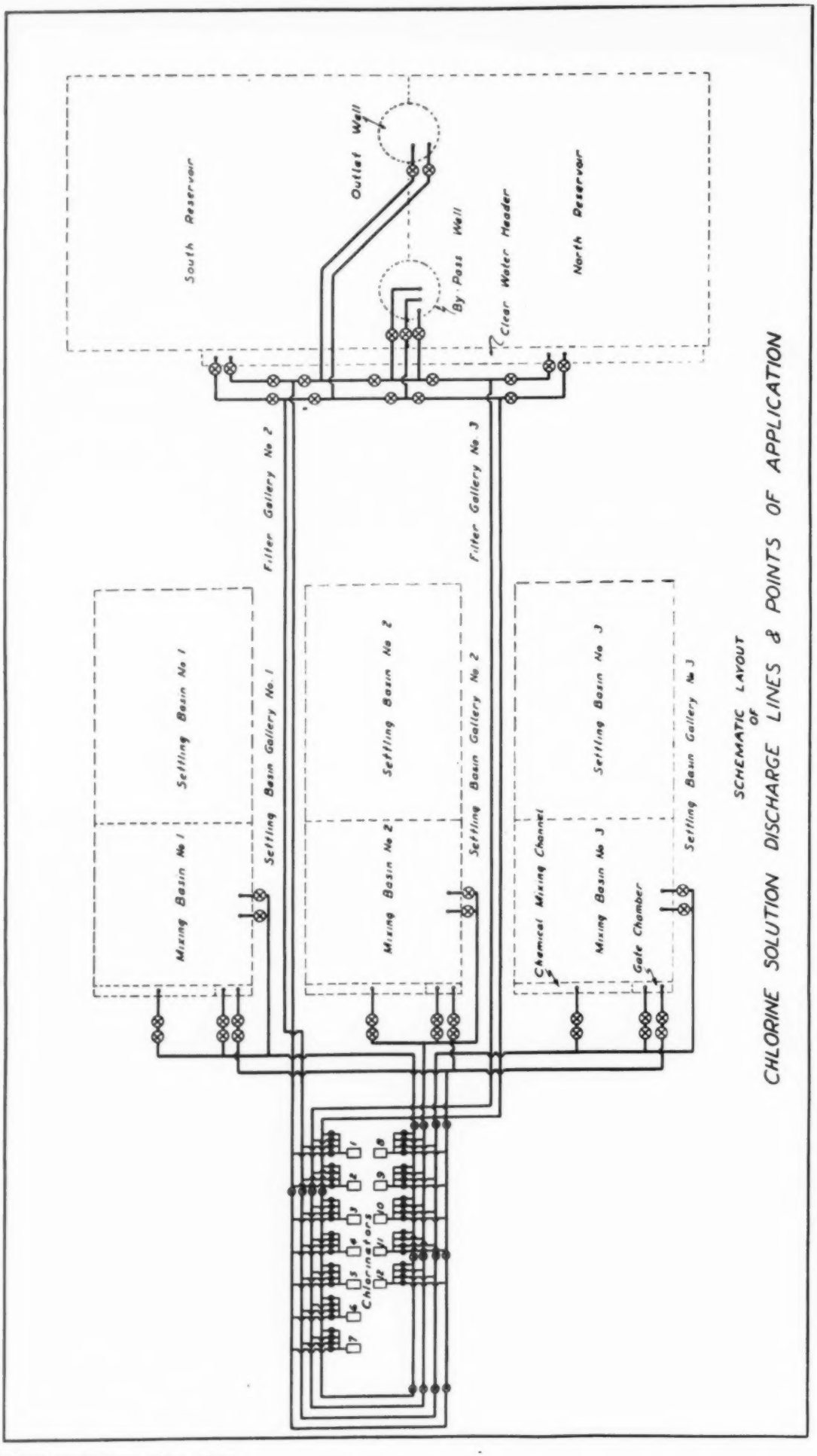


Fig. 5—Schematic Layout of Chlorine Solution Lines to 23 Points of Application

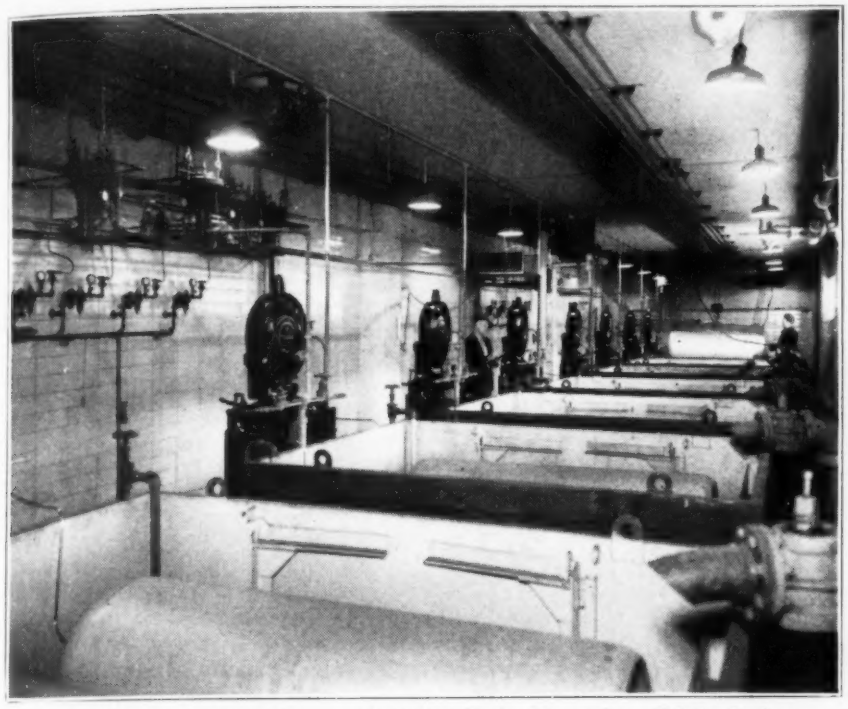


Fig. 6—Chlorine Scale Room with Safety Tanks Mounted on Toledo Scales

Note One Battery of Pressure Reducing Valves, One on Each Gas Line (upper left). The Pressure-Suction Ventilating System will Change Air in Scale Room Every Two Minutes.

Eight pressure reducing valves are located on the chlorine gas lines between the manifolds and the headers in the chlorinator room. The gas pressure is reduced from container pressure to 45 lbs. This lessens the possibility of re-liquefaction of the chlorine gas in the lines or at the chlorinator, and also maintains a constant pressure on the chlorinators.

The ¾ in. chlorine valves, 75 in number, are located at points on the lines to give the greatest flexibility. These valves are Crane Company's No. 1644 chlorine valves. The metal of the disc, disc stem ring, and body seat is Hastelloy C. The stem is monel metal. Koroseal has been found the best packing for the stems.

Chlorinators

Eleven Wallace and Tiernan chlorinators, and one "homemade" machine have been installed in the chlorinator room—(Fig. 7). Room is available for six more machines. Four of the chlorinators have capacity of 2500 lbs. each in 24 hours, and seven have a capacity of 750 lbs. each. The tray water for the machines is maintained at about 70° F. by a separate hot water heater. The homemade machine is of the "rotometer" type and has a capacity of 3000 lbs. per day. This machine operates under 30 to 40 lbs. pressure.

Chlorine Solution Lines

All chlorine solution pipe lines, specials and valves are rubber-lined iron. Four 5 in. pipe lines extend almost around the chlorine room. Each chlorinator connects to all four lines. The connections to the headers from the chlorinators are of 3 in. size.

Fig. 5 is a schematic diagram which shows the 23 points of chlorine application and the multiple discharge lines to each of the application points. Four and five inch piping is used to convey the solution to the application points. The chlorine solution piping system is very flexible, permitting use of any number of chlorinators to one or more points of application. The long solution lines for post-chlorination and by-pass chlorination are unusual for water purification practice. Because of the straight-line flow of water through the plant, the distance from the chlorinator room to the filtered water reservoirs is considerable. It was necessary to have such long lines, or two chlorination plants. One plant with long lines was selected as being the cheaper to operate. The maintenance of a high pre-chlorine dosage so far has left little to be done by post-chlorination. There are 7435 ft. of rubber-lined steel piping and 95 Hills-McCanna rubber-lined diaphragm valves of the pinch type in the chlorine solution discharge system. Excellent service has been obtained from the rubber-lined piping and Hills-McCanna diaphragm valves during the three and one-half years of operation of the chlorination equipment.

Water Pressure Pumps

The process water pressure in the filtration plant is not enough to give good operation of the chlorinators, particularly when used for post-chlorination. Booster pumps are used to increase the pressure from about 20

Fig. 7—Chlorinator Room

Battery of Six W&T Chlorinators on Left Provide Post-chlorination. Battery of Five 2,500 lbs./day Chlorinators on Right Provide Pre-chlorination.

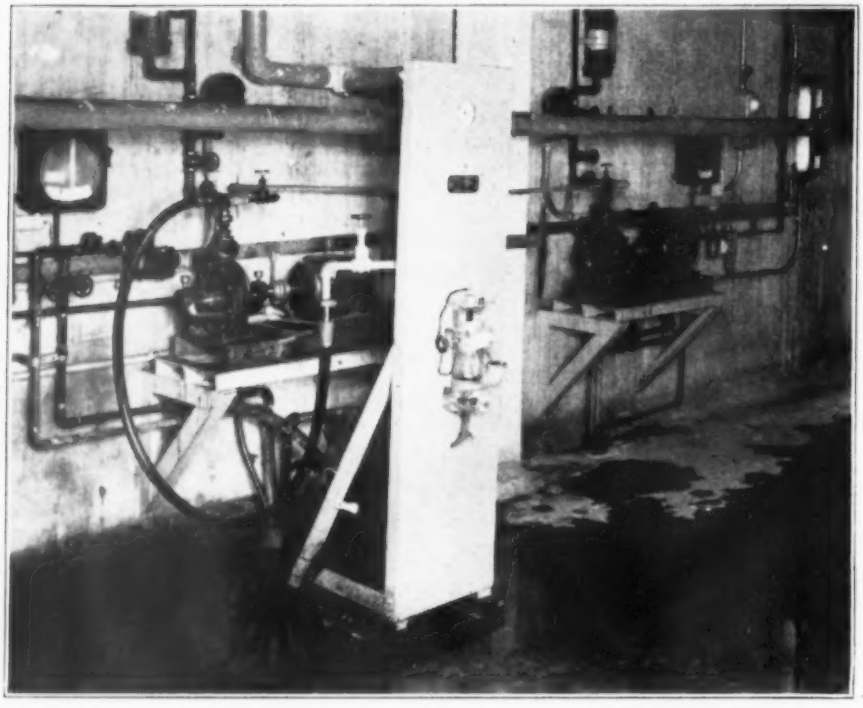


Fig. 8—Two of the Sampling Pumps Located Throughout the Plant and Delivering to the Laboratory

A Portable Unit from One of the Residual Recorders is Checking Residual Chlorine at Point of Sampling.

lbs. to 70 lbs. at the level of the chlorinators. There are three electric-driven centrifugal booster pumps, each with capacity of 200 gpm. which are located on the +17 ft. floor level under the chlorine room. There are duplicate suction and discharge lines for the booster pumps to provide for continuity of operation in the event one of the lines is out of service for repairs.

Since it is necessary to keep the chlorinators in service all the time, even should there be a power outage at the plant, the booster pumps may be operated by current from the turbo-generator located in the boiler room. High pressure steam is maintained at the plant all of the time to operate emergency equipment and provide hot water for process purposes.

Safety Precautions

In addition to the provision of caustic soda solution for absorbing chlorine from a leaking container, an extensive emergency ventilating system is installed in the chlorine scale room and the chlorinator room to remove chlorine gas leakage. The emergency ventilating system consists of a combination of a pressure system which discharges fresh air under pressure near the ceiling of the rooms and a suction system which removes the heavy chlorine-air mixture through openings in the floor. The system is capable of providing a complete air change every two minutes in the chlorine rooms.

Another safety device provided is a "Duriron" water ejector which has a long rubber hose coiled on a reel connected to the suction side of the ejector. A rubber funnel is attached to the other end of the rubber hose. Minor chlorine leakage from joints and valves can be worked on without danger or inconvenience by sucking the leaking gas into the water ejector through the rubber funnel and hose. Two of these ejectors and hose reels are provided in the scale room.

Gas masks, a Solvay ton chlorine container emergency kit and other safety equipment is available at all times.

CONTROL OF CHLORINATION

The raw water supply for the South District Filtration Plant which is obtained from Lake Michigan is, as stated previously, subject to pollution by sewage and industrial wastes from the large Calumet industrial area located on the shore of Lake Michigan to the south of Chicago. These wastes, under the influence of southerly winds, may travel to the plant intake in a few hours. The water, after treatment at the plant, flows by gravity through approximately 21 miles of tunnels to three high lift pumping stations located inland, from which the water is distributed to an area of approximately 162 square miles, of which 112 square miles is within the city limits and about 50 square miles is in suburban communities. An additional high lift pumping station which is operated during the summer months by the Chicago Park District for sprinkling purposes, is also supplied by gravity through a branch tunnel. The water receives no further chlorination after leaving the filtration plant. On the water tunnel system there are 21 shafts which have their tops at street level. Special precautions have been taken to protect each of these shafts from entry of surface water pollution, but because of the potential hazard of such contamination it has been Chicago's policy to maintain a substantial "free" residual chlorine in the water flowing through the tunnels as a safety measure.

A "free" residual chlorine between 4.0 and 5.0 lb. per million gallons (0.48 and 0.62 ppm.) is maintained in the water leaving the filtration plant outlet. Because of the fluctuating quality of the raw water supply, it is necessary to have close control over the chlorination treatment in order to at all times maintain active "free" residual chlorine in the plant effluent.

Chemical Control Engineers

Supervision over the chlorination treatment is carried out by Chemical Control Engineers, who operate on shifts the same as the operating employees. The chlorine dosages depend on the wind direction, free ammonia nitrogen content of the raw water, and the residual chlorine in the water in various parts of the plant as shown by chemical tests made in the control laboratory and by continuous records from the residual chlorine recorders receiving water from the numerous remote points. Normally, the chlorination dosage is split with the larger portion of the chlorine dosage being applied at the entrance of the basin venturi meters before the water enters each of the three rapid mixing channels, and a relatively smaller dosage is applied to the filtered water as it enters the north and south filtered water reservoirs. Enough chlorine (usually 1 to 3 lbs. per million gallons) is applied at the entrance to the filtered water reservoirs to provide the 0.48 to 0.62 ppm. required "free" chlorine in the water as it leaves the outlet shaft. On rare occasions the residual chlorine in the water in the reservoirs has been too low, and the deficiency was made up by applying chlorine near the top of the outlet shaft, as the water left the plant.

Residual Chlorine Recorders

Continuous sampling of water from various parts of the plant is provided by motor driven centrifugal pumps

which deliver water through copper pipe to sampling faucets located in the control laboratory and in some cases also to cells which measure the residual chlorine and record the data continuously on indicating and recording gauges located on the control room panel board—Fig. 8. There are seven Wallace & Tiernan residual chlorine recorders located in the control room; three of the recorders show the residual chlorine in the water at the entrance to each of the flocculators a short time after pre-chlorination, one recorder measures the residual chlorine in the settled water at the outlet of one of the settling basins, two recorders show the residual chlorine in the north and south filtered water reservoirs and one recorder measures the residual chlorine in the water at the bottom of the outlet shaft as it leaves the plant. These recorders give continuous records of the residual content of the water in various parts of the plant—Fig. 9. With this data any deficiency of residual chlorine in the water flowing through any part of the plant is shown immediately and can be made up before the water leaves the plant by applying chlorine at one of the numerous points of application provided in the plant—(See Fig. 5).

SOUTH DISTRICT FILTRATION PLANT
RESIDUAL CHLORINE IN WATER SUPPLY
1948

MONTH 1948	AVERAGE RESIDUAL CHLORINE POUNDS PER MILLION GALLONS				
	MIXING BASINS	SETTLING BASINS	PLANT OUTLET	SOUTH DISTRICT PUMPING STATIONS	SOUTH DISTRICT DISTRIBUTION SYSTEM
JANUARY	7.0	6.6	6.0	5.3	2.8
FEBRUARY	7.1	6.6	6.1	5.5	3.2
MARCH	8.0	6.6	6.1	5.2	3.4
APRIL	7.7	6.4	5.7	4.8	3.7
MAY	7.7	6.2	5.6	5.1	3.4
JUNE	7.6	6.2	5.7	4.6	3.5
JULY	5.2	3.9	4.9	4.6	2.9
AUGUST	2.3	1.2	5.3	4.5	2.9
SEPTEMBER	0.7	0.5	5.5	4.0	2.9
OCTOBER	4.1	2.7	5.7	3.5	2.9
NOVEMBER	4.4	3.0	5.9	3.8	2.6
DECEMBER	5.5	4.0	5.9	3.9	2.7
YEAR	5.6	5.0	5.7	4.6	2.7

Chemical Tests for Residual Chlorine

Chemical tests of residual chlorine of samples from various points in the plant are made routinely in the control laboratory every hour and more often, if necessary. These tests are made by means of the Wallace and Tiernan amperometric titrator which gives the "free," "combined" and "total" residual chlorine in the water. The chlorine treatment is regulated so that the "combined" residual chlorine is held to not more than 0.1 to 0.2 pounds per million gallons and seldom as much as 0.3 lbs. These tests are used to test the accuracy of the residual chlorine recorders. Also, on each shift the chemist runs comparative residual chlorine tests by means of the ortho-tolidine and starch iodide methods, in addition to the amperometric titration, in order to have a general check on the tests.

Residual chlorine recorders are installed also at each of the high lift pumping stations to obtain a continuous record of the residual chlorine in the water entering the distribution system from each of the stations.

Free Ammonia Nitrogen

In general, the free ammonia nitrogen content of the water is the most important factor in determining the chlorine dosage necessary to obtain

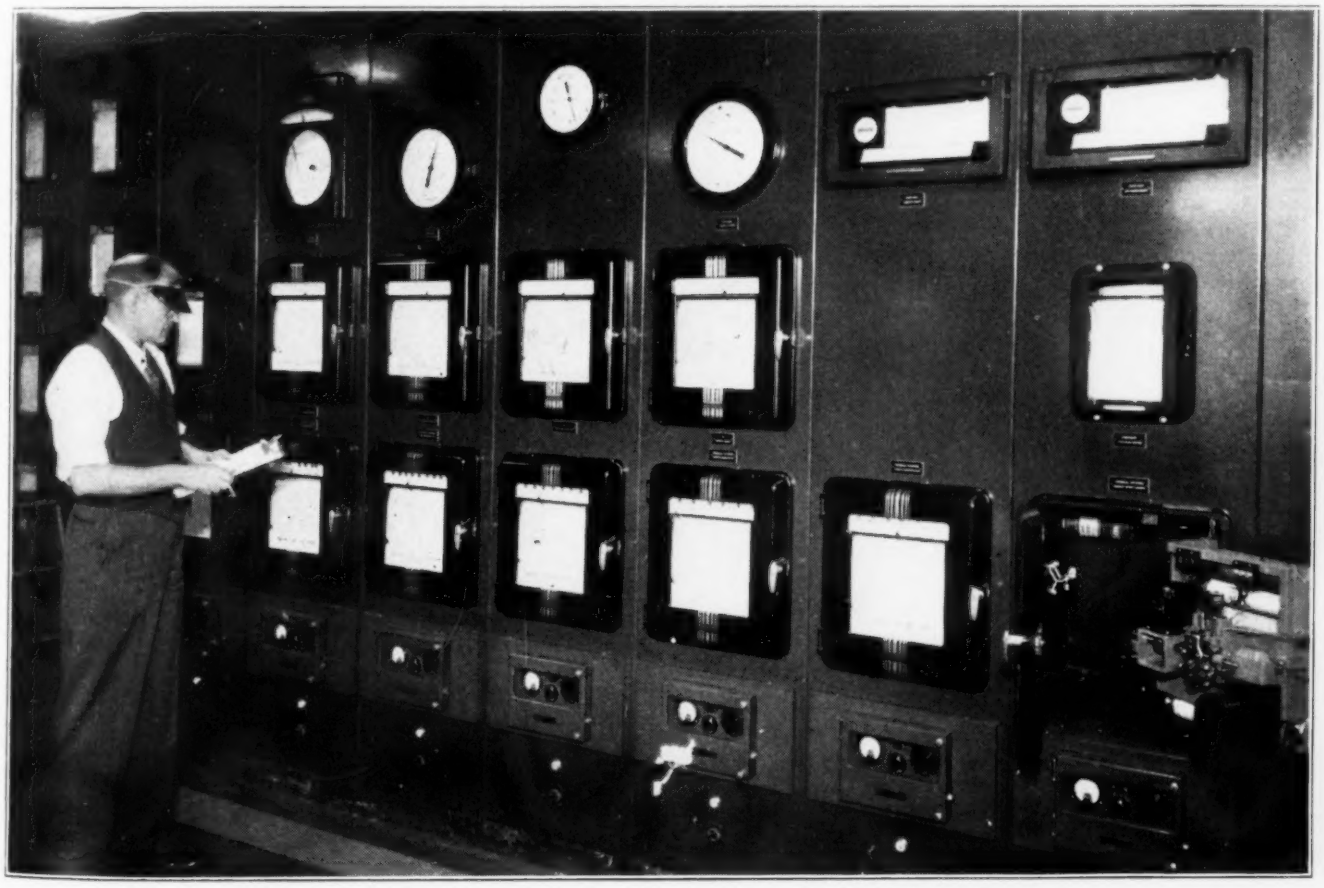


Fig. 9—Chlorination Control Room Board Showing Seven Residual Chlorine Recorders

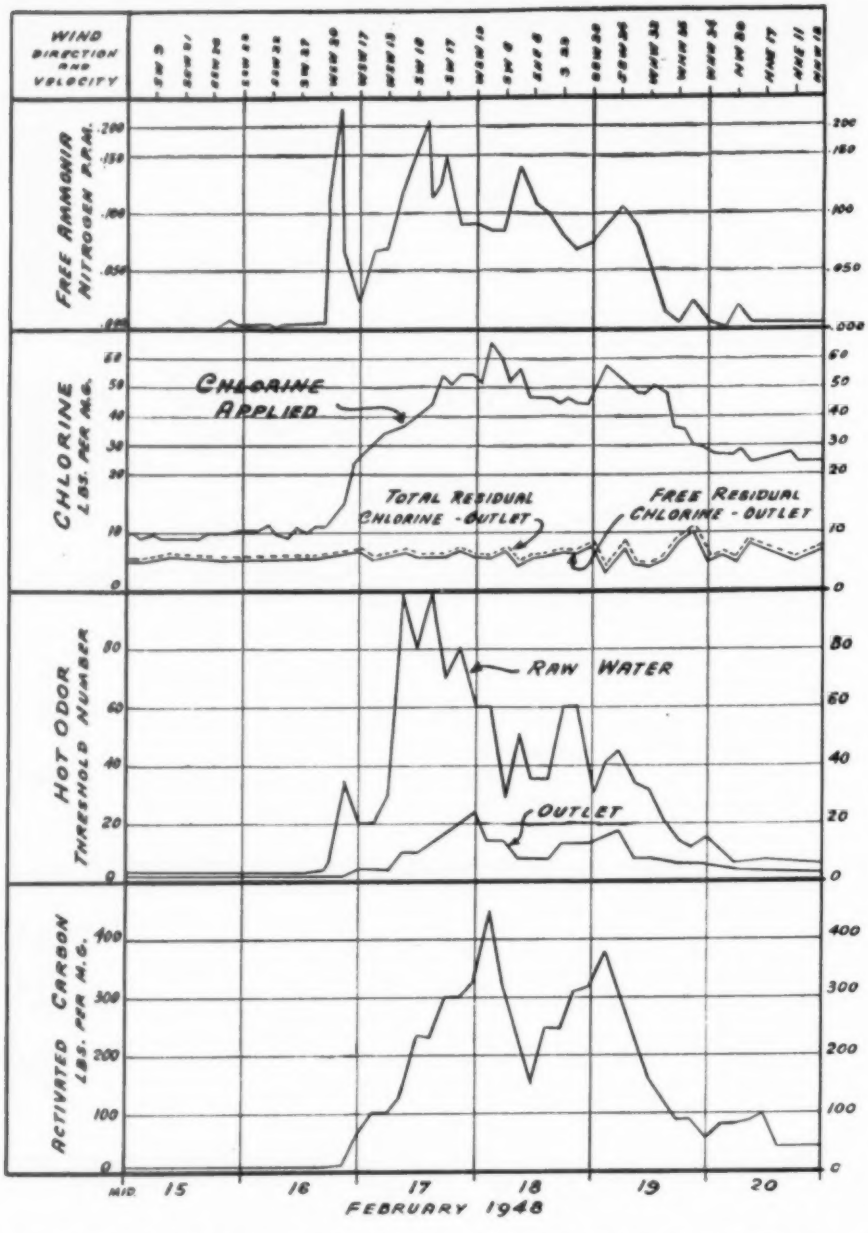


Fig. 10—Record of Relationship Between Free Ammonia Content of Raw Water and Chlorine Requirement to Maintain "Free" Residual Chlorine

These Relationships are all-important in Producing a Taste and Odor Free Water and Insured Bacterial Destruction.

the desired "free" residual chlorine in the outlet water. This test has proven to be the most sensitive indicator of arrival of sewage and industrial waste pollution at the plant intakes. The raw water for the plant normally has ammonia nitrogen content of between 0.000 to 0.005 ppm. An increase to 0.01 ppm. usually indicates the arrival of polluted water at the intake. An ammonia content of 0.05 ppm. usually requires about 50% greater chlorine dosage to "breakpoint" the water, and is often accompanied by objectionable and industrial waste odors. Ammonia nitrogen content of 0.10 ppm. occurs when the water is grossly polluted by sewage and industrial wastes and requires extremely high chlorine dosages. The ammonia nitrogen content found during the most serious pollution periods has rarely been in excess of 0.20 ppm. The ammonia nitrogen test is made routinely on the raw water at intervals of every two hours or every hour when the ammonia nitrogen is over 0.05 ppm. The test is made by nesslerization of the distilled sample in accordance with the A. P. H. A. Standard Methods, 9th edition.

Effect of Activated Carbon Application

Another factor in determining the chlorination dosage is the amount of activated carbon applied at the plant to remove objectionable odors from the raw water. During odor periods the major portion of the carbon is applied in the rapid mixing channels and the remainder of the dose to the settled water as it flows to the filters. Experience has shown that the activated carbon application in the mixing channels increases the chlorination dosage required, in approximately the ratio of 1 lb. of chlorine per million gallons for each 10 lbs. per million gallons of carbon applied.

A chart (Fig. 10) shows the relation between free ammonia nitrogen and odor threshold, and the chlorine and carbon dosages during a period when the raw water supply was highly polluted with sewage and industrial wastes. During this period "free" residual chlorine was maintained at the normal level.

Chlorine Used

In 1948 a total of 1,749,265 lbs. of chlorine was used to treat the water at the South District Filtration Plant. The average chlorine dosage was 14.7 lbs. per million gallons. The maximum daily chlorine dosage was 49.5 lbs. per million gallons (6 ppm.) and the minimum daily dosage was 9.0 lbs. per million gallons. The maximum total amount of chlorine applied during a day was 16,056 lbs.—8.02 tons. The amount of water treated at the plant during 1948 averaged 319.20 million gallons per day with a peak day of 405.7 million gallons and a peak hourly rate of 512 million gallons per day.

Operation of the South District Filtration Plant is a function of the Department of Public Works—Oscar E. Hewitt, Commissioner of Public Works; W. W. DeBerard, City Engineer.

Chester E. Albright Dies

Chester E. Albright, who was president of the Philadelphia consulting firm of Albright and Friel until his retirement in 1945, died in Philadelphia on March 29.

A graduate of Lafayette College in 1883, Mr. Albright established a consulting engineering office in Philadelphia in 1890. In 1904 this firm became Albright and Mebus and in 1931 the firm of Albright and Friel was formed. Mr. Albright was succeeded as president of this firm by Francis S. Friel in 1945.

From 1916 to 1920 Mr. Albright served as Chief Engineer of the Bureau of Engineering and Surveys for the City of Philadelphia.

A.W.W.A.'S. TECHNICAL PROGRAM

Chicago Convention May 30-June 3

MONDAY MORNING—MAY 30

Water Purification Division

Highlights of the Operation of the New Chicago Filters
John R. Baylis

Taste and Odor Control in Water Treatment Plants at Lower End of Lake Michigan
Leo Besozzi

Design and Operation Control of Small Water Treatment Plants
Martin E. Flentje — Ivan M. Glace

Discussion
E. R. Dougherty — H. L. Keinath
W. H. Willsmann — A. B. Daugherty

MONDAY MORNING—MAY 30

Water Works Management Division

Effects of State Highway Construction Policies Panel Discussion
L. W. Grayson — W. G. Banks
Arthur C. King

Making Municipal Reports Interesting
E. B. Mayer

Types of Insurance Protection for Municipal Water Departments Panel Discussion
A. A. Morey — C. G. Bourgin
R. O. Ellis — E. C. Schwier

MONDAY AFTERNOON—MAY 30

General Session

Water Department Operations Under City Manager Administration
G. E. Arnold — Reeves Newsom

Municipal Water Department Operations in the Chicago Area
W. W. DeBerard — L. D. Gayton

Report of the Committee on Laying Cast Iron Water Mains
J. P. Schwada

Experiences with Cement as a Jointing Material
Panel Discussion
D. L. Maffitt — C. F. Wertz
L. E. Goit

TUESDAY MORNING—MAY 31

Water Resources Division

Open Forum—Ground Water Law—Current Developments
C. H. Bechert — J. C. Thompson
G. S. Knapp — C. V. Youngquist
H. T. Critchlow — L. F. Warrick
A. H. Johnson — S. H. Cathcart

TUESDAY MORNING—MAY 31

Committee on Water Works Administration

Preliminary Report of the Committee on Compensation of Water Works Personnel*
L. A. Smith, Chairman

(*To be followed by reports of other Water Works Administration committees.)

TUESDAY AFTERNOON—MAY 31

General Session

Ethics of the Water Works Industry Panel Discussion
Malcolm Pirnie — W. F. Rockwell
S. B. Morris

The Present Set-up of the British Water Industry—With Some Thoughts for the Future
Henry Berry (London, Eng.)

Wisconsin Policies Concerning Water Department Funds
W. F. Whitney

WEDNESDAY MORNING—JUNE 1

Water Purification Division

Processing Water for Industry—Rayon, Paper, Soft Drinks
R. W. Haywood, Jr. — Bert H. Wells

Bacterial Reproduction in Zeolite Layers—Panel Discussion
W. W. Aultman — W. A. Mallmann
George Klumb — H. C. Marks

WEDNESDAY MORNING—JUNE 1

Water Works Management Division

Committee Report—Regulation of Water Use for Air Conditioning
F. C. Amsbary—Chairman

Committee Report—Water Main Extension Policy
L. S. Finch—Chairman

Diversion of Water Works Funds—Panel Discussion
Wendell R. LaDue, Moderator
W. C. Morse — J. C. Detweiler
D. D. Gross — C. M. McCord
A. R. Davis — W. H. Weaver
M. S. Dutton — A. E. Bell
S. S. Anthony

WEDNESDAY AFTERNOON—JUNE 1

General Session

Committee Report—Industry Policy—Fluoridation of Public Water Supplies
A. P. Black—Chairman

Recent Research on the Transmission of Poliomyelitis (With Particular Reference to the Hypothetical Involvement of Water Supplies)
Dr. Kenneth F. Maxcy

Water Supply Quality—Panel Discussion
A. D. Weston, Moderator
C. R. Cox — D. B. Lee
T. A. Filipi — A. N. Beck

THURSDAY MORNING—JUNE 2

General Session

Minimizing Service Interruptions Derived from Transmission Line Failures
W. W. Brush — S. L. Kerr
H. T. Munn

Atlanta Adopts Modern Billing Methods and Equipment
Paul Weir

Rethinking Water Rate Structures—Panel Discussion
L. E. Ayres, Moderator
C. H. Capen — M. P. Hatcher
A. P. Learned — Reeves Newsom
E. F. Dandridge — Paul Weir
N. S. Jacobs — W. A. Kunigk
R. H. Ellis

THURSDAY AFTERNOON—JUNE 2

Water Purification Division

Open Air Reservoirs—Committee Report
N. J. Howard—Chairman

Disposal of Wastes from Purification and Softening Plants
W. W. Aultman—Chairman

Purification Wastes
Paul Haney

Softening Wastes
A. P. Black

Loading Capacities of Water Treatment Plants
H. O. Hartung—Chairman

Water Distribution System Problems
J. C. Vaughn—Chairman

Standard Methods—Water and Sewage
R. L. Derby—Chairman, A.W.W.A. Committee
H. A. Faber—Chairman, Joint Editorial Board

THURSDAY AFTERNOON—JUNE 2

General Session

Water Departments' Use of Radio—Panel Discussion
M. B. Cunningham, Moderator
Carl Hechmer — Adolph Damiano
F. E. Dolson — N. S. Bubbis

Advantages and Limitations of Automatic Equipment
V. C. Lischer

Steel Pipe Inspection—Ten Helpful Hints
Edward Clark

Discussion
Fred Randlett — Russell C. Beam

FRIDAY MORNING—JUNE 3

Water Resources Division

Multipurpose Reservoir Effect on Municipal Water Supply
F. W. Kittrell — F. W. Thomas

Open Forum
Effects of Land Use on Water Resources
H. E. Hudson, Moderator
C. B. Brown — G. J. Rohan
V. W. Flickinger

FRIDAY MORNING—JUNE 3

Water Works Practice Committee

Proposed Standards for Deep Well Turbine Pumps
P. H. Brown

Survey Report—Effects of Pump Lubricants Upon Quality of Water from Deep Wells
L. E. Ordelheide

Water Works Practice Committee Projects—Open Discussion

AN UNUSUAL WATER SERVICE POLICY

Wherein Kalamazoo Installs and Maintains all Water Service Connections Main to Meter.

by
EARL E. NORMAN
Manager
CITY WATER & LIGHT UTILITIES
KALAMAZOO, MICH.

PREVIOUS to 1934 a report about a leak in a Kalamazoo water service connection would go about like this:

Customer:

"There is a leak in my yard."

Water Clerk:

"What is your address please?" (The water clerk, if she is smart, always asks the address before giving out any further information. If she does not obtain the address then, she probably won't obtain it later).

Customer:

"235 South 23rd Street."

Water Clerk:

"Well, Mrs. Jones, you see that is something for *you* to have repaired by your plumber. That is your responsibility. The Water Department does not make such repairs nor is it responsible for them.

Customer:

"Well it's none of my business. The water can keep on leaking as far as I'm concerned. I'm not going to spend any of my money for it. It is your water that is going to waste. I thought you would like to be told about it, but if you don't—good-by."

Water Clerk:

"Just a minute Mrs. Jones, I'm sorry, but if you don't have that leak repaired within a reasonable length of time, we will be obliged to shut off the water."

Customer:

"Well my husband is a mechanic, can he make the repair himself?"

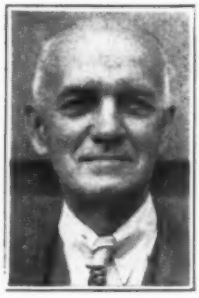
Water Clerk:

"I'm sorry Mrs. Jones, our regulations require that the repair be made by a licensed plumber. After all, we must know who does the work."

Customer:

"All right, we'll do it, but it looks to me as if you were in cahoots with the plumbers." Telephone---BANG!

In an endeavor to eliminate such conversations, we have assumed the repair and maintenance of all service connections from the main to the meter, no matter where the meter is located, including those installed by ourselves and including those installed in the past by plumbing contractors.



The Author

Since 1934 the city of Kalamazoo, Michigan, has been installing and maintaining all water service connections from the main to the customer's water meter, regardless of where located. Having learned of this unusual but seemingly meritorious policy and practice of a water utility, the editor of Water & Sewage Works *has prevailed upon the author to tell of the scheme and discuss the pros and cons of this novel practice and recite Kalamazoo's experience during the fourteen years wherein the city owned water utility has assumed responsibility for water service facilities, not only to the customer's property line but through to the meter, just as has long been the practice of electric and gas utilities in supplying electricity and gas.*

After all, no one should be more interested in maintaining a service connection in its proper condition than the water utility. It is directly to the water utility's interest to see that proper materials are used for the water service line and that leaks are reduced to a minimum. As the lady has so unmistakably said, "It is your water that is going to waste." In fact, we see no difference between the maintenance of a service connection than the maintenance of a water main. We believe it is our job to furnish water to the discharge nozzle of the meter without any expense on the part of the customer except that which he pays in the form of water rates.

Service Installation Charges

Let no one misinterpret our policy and assume that we install service connections free of charge. We charge for them on the following basis:

	For first 10 feet.	For each additional ft.
¾"	$42.00	$1.20
1¼"	$63.00	$1.30
2"	$94.00	$1.40

Since we install and maintain the service connections ourselves, we make no mention to the customer of the material that is used. We select the material that best fits the job. Sometimes we use copper, sometimes lead and sometimes cast iron. (We use cast iron as small as 2 inch.) In especially favorable conditions on short services through clean sand and gravel, we sometimes use galvanized wrought-iron. If the customer raises a question about the material used, we explain to the customer that *we* are responsible and *we* determine the best material to fit the job.

"But this is so expensive," some utilities say. Yes, it costs money, you do not get it for nothing. It has been costing us about seventy-five cents per customer per year, but we believe it is seventy-five cents well spent.

And Today

Now a conversation relative to a water leak between the water meter and main runs as follows:

Customer:

"There is a water leak in my yard."

Water Clerk:

"What is your address, please?"

Customer:

"235 South 23rd Street."

Water Clerk:

"Thank you, Mrs. Jones, we'll see that it is taken care of. There will be no charge for this service."

Customer:

"Thank you very much. It is a pleasure to do business in such a manner."

Which is the better public relation?

SIMPLIFIED AMPEROMETRIC TITRATION APPARATUS FOR DETERMINING RESIDUAL CHLORINE IN WATER

by
W. A. MAHAN
Chief Chemist
MUNICIPAL WATER WORKS
LITTLE ROCK, ARK.

The Author

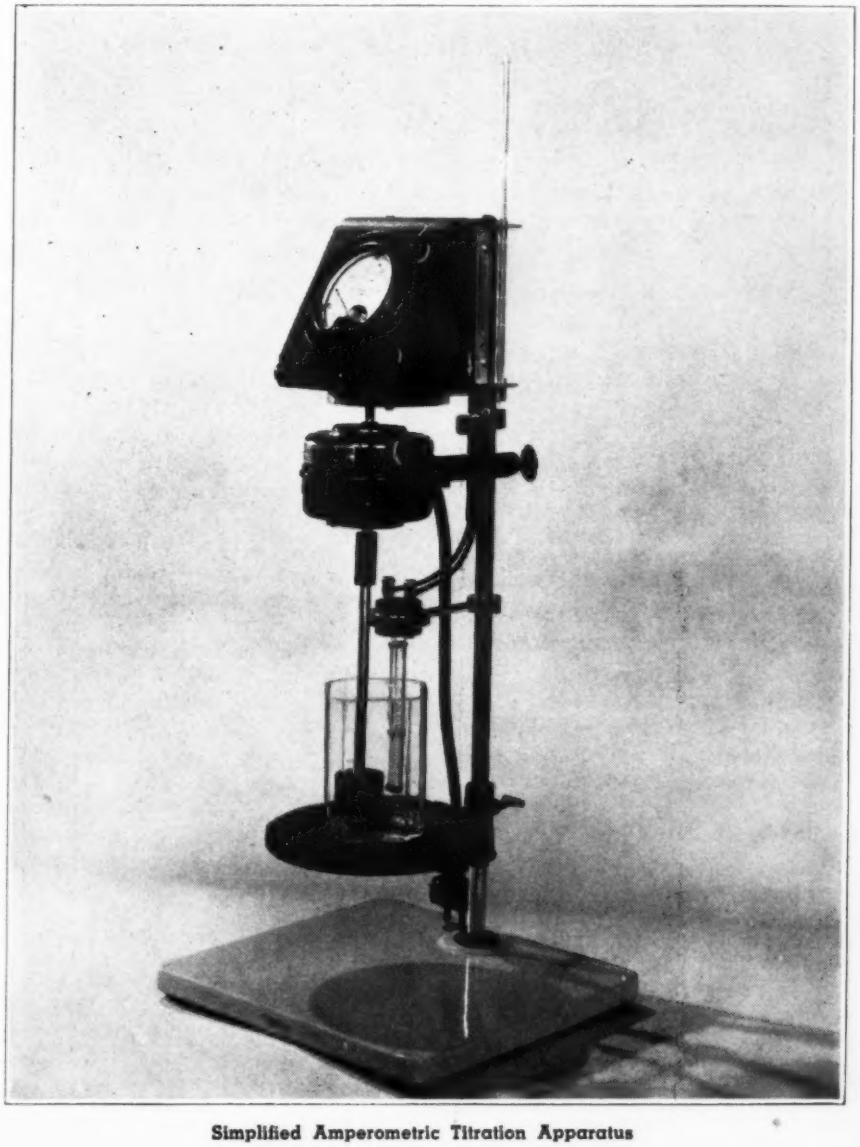
THE determination of chlorine by titration with sodium arsenite, in neutral solution, has long been known to be one of the most accurate methods for the determination of this element [1], provided that some means of locating the end-point of the titration is available. In the determination of chlorine in bleaching powder and strong chlorine water solutions, starch-iodide paper has been used to determine the end-point of the arsenite titration but the sensitivity of this reaction is not great enough for use in determining residual chlorine in water.

This end-point can be accurately determined, in very weak, neutral chlorine solutions, by amperometric titration as demonstrated by Washburn [2], Kolthoff and Pan [3] and others. The practical application of this method for determining chlorine residuals in water, both as free chlorine and as chloramines, has been applied by Marks and Glass [4] and by Haller and Listek [5], and an instrument for making this determination is now being manufactured and sold by the Wallace and Tiernan Co. of Newark, N. J., under the trade name, "Amperometric Titrator."

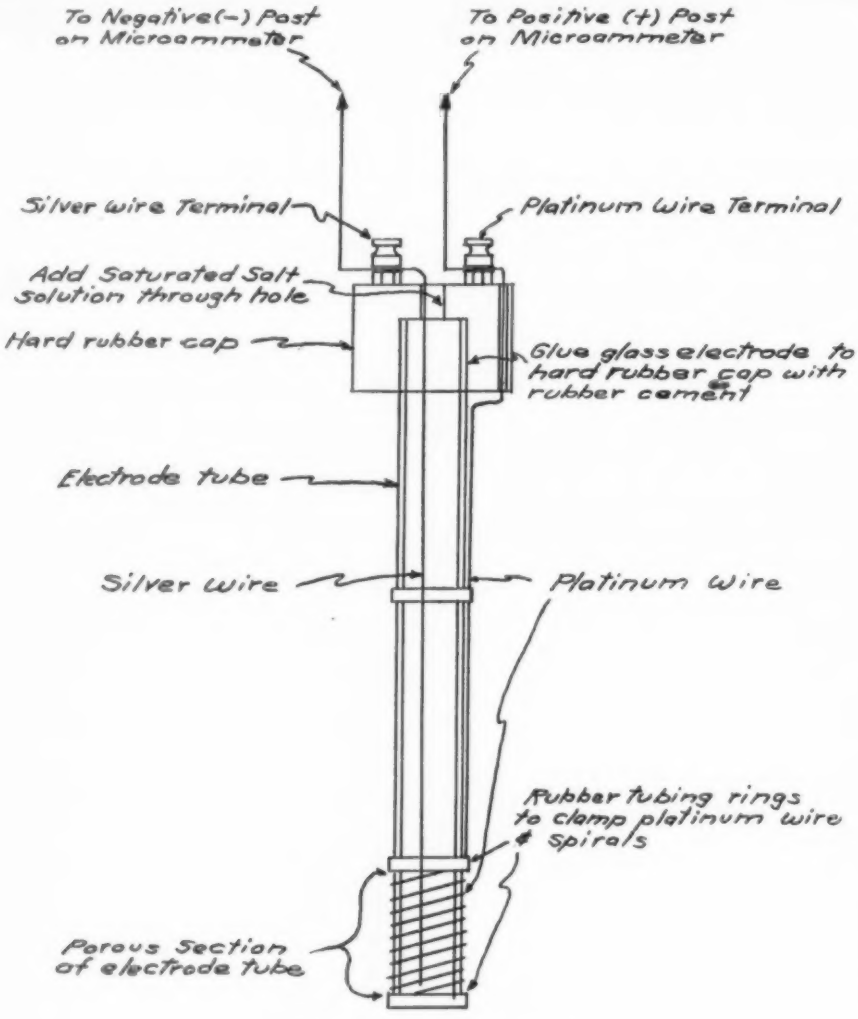
In the application of this method, elemental chlorine, hypochlorites, hypochlorous acid, and free iodine are titrated quantitatively by sodium arsenite in neutral solution. The presence of chloramine in the sample does not interfere, which fact allows free chlorine to be determined in a water sample which also contains chloramine. When potassium iodide is added to water containing free chlorine, chloramines or both, free iodine is liberated quantitatively by both forms of chlorine and may be titrated by the arsenite. From these reactions, it can be seen that both free and combined chlorine can be determined by this method. It is essential that the sample remain neutral throughout the entire titration and this is accomplished by adding the proper amount of a suitable buffer before the titration is begun. When neutrality is maintained, there is no interference by any of the substances which normally give trouble when the o-tolidine method is used, such as iron, manganese or nitrite [4] [5].

Apparatus

From information received from the Haller and Listek paper [5], and also from personal communications with Dr. John F. Haller of the



Simplified Amperometric Titration Apparatus


To Negative(−) Post on Microammeter
To Positive (+) Post on Microammeter
Silver wire Terminal
Platinum Wire Terminal
Add Saturated Salt solution through hole
Hard rubber cap
Glue glass electrode to hard rubber cap with rubber cement
Electrode tube
Silver wire
Platinum wire
Rubber tubing rings to clamp platinum wire spirals
Porous Section of electrode tube

Silver-Platinum Electrode for Titrator

Mathieson Chemical Corp., the author has constructed an amperometric titration apparatus for determining chlorine residuals in water at the laboratory of the Little Rock Municipal Waterworks. A photograph of the completed instrument appears in Fig. 1. This apparatus was fairly simple to construct and requires no calibration, since it is only an end-point indicator, the chlorine present in the sample being determined by the arsenite.

The principal parts consist of a microammeter, a special silver-platinum, porous glass electrode and a rapid stirring device. All parts are mounted on a porcelain top support stand by means of clamps.

The electrode tube was fabricated to the author's specifications by the Ace Glass Co., of Vineland, N.J., and consists of a 4-inch piece of 10 mm. Pyrex glass tubing fused to a 1-inch piece of fritted glass tubing, 10 mm. in diameter and closed on the lower end. The porosity of the fritted section was Corning Glass Co. Designation "Fine" (F). This porosity allows the saturated salt solution, which fills the electrode tube when in use, to diffuse out very slowly.

On the outside of the tube, 24 inches of No. 26 B.&S. platinum wire are wound spirally around the fritted section, the spirals being secured at each end by a small ring of rubber tubing. The upper end of the platinum wire passes up the outside of the tube and fastens to a terminal post on the electrode cap, which is made of hard rubber. A 5-inch length of No. 22 B.&S. pure silver wire passes down through the inside of the electrode tube and is fastened, at the upper end, to a terminal post on the electrode cap. The platinum wire terminal is connected to the positive (+) post on the microammeter and the silver wire terminal is connected to the negative (—) post on the microammeter.

Although it is the usual practice to supply a small polarization current from an outside source in such amperometric titrations, Haller and Listek [5] demonstrated that the silver-platinum electrode functioned adequately as a primary cell and required no external current and also, when this procedure was followed, a more constant sensitivity was provided.

In the construction and operation of the apparatus described in this paper, the author has followed the Haller and Listek method, and the only outside current required is that needed to operate the stirring equipment and has no connection with the determination of the arsenite end-point. The construction of the electrode and connections to microammeter are shown in Fig. 2.

The microammeter was purchased from a local radio supply house and is a Weston microammeter with a scale range of 0-20 microamperes. The motor-driven stirring device was purchased from the Fisher Scientific Co., of St. Louis, Mo. It is equipped with a ¼-inch stainless steel shaft 9 inches long and a special centrifugal-type hard rubber stirring head, which was machined out of hard rubber stock in the plant machine shop. This type of stirrer head provides very rapid stirring without splashing. It is very important that efficient stirring be used in this determination.

The sample jar is square and has a capacity of 250-300 ml. The jar is supported by a swinging support plate which allows samples to be easily placed under and removed from the instrument. The use of a square jar tends to reduce splashing when the sample is stirred. Both jar and support plate can be purchased from any laboratory supply house.

The over-all cost of this instrument was approximately $50.00, which is broken down as follows:

Microammeter (with case)	$18.00
Motor-driven Stirrer	7.50
Special porous glass electrode tube	4.00
Support stand	4.25
Swinging support plate	.75
Sample jar	.20
Platinum wire	7.80
Silver wire	1.78
Clamps and wiring	5.00
Total Cost	$49.28

Reagents

The amperometric determination of free and combined chlorine requires the use of six reagents, all of which are stable for long periods of time, with the exception of the Standard Arsenite solution, which should be prepared fresh about every 4 or 5 days.

Since even distilled water has an appreciable chlorine demand, all reagents should be prepared with zero chlorine demand water, to prevent loss of chlorine from the sample due to the addition of the reagents.

The preparation of this special water is given in the reagent list below.

(1) *Neutral Buffer Solution.*—100 grams of sodium dihydrogen phosphate monohydrate ($NaH_2PO_4 \cdot H_2O$) and 400 grams of disodium hydrogen phosphate dodecahydrate ($Na_2HPO_4 \cdot 12\,H_2O$) are dissolved in water and diluted to 1 liter. Use zero chlorine-demand water to make up this solution.

(2) *Saturated Salt Solution.*—Add 50 grams of C.P. Sodium Chloride (NaCl) to 100 ml. of zero chlorine-demand water and shake at intervals until saturated. Let excess salt settle before using.

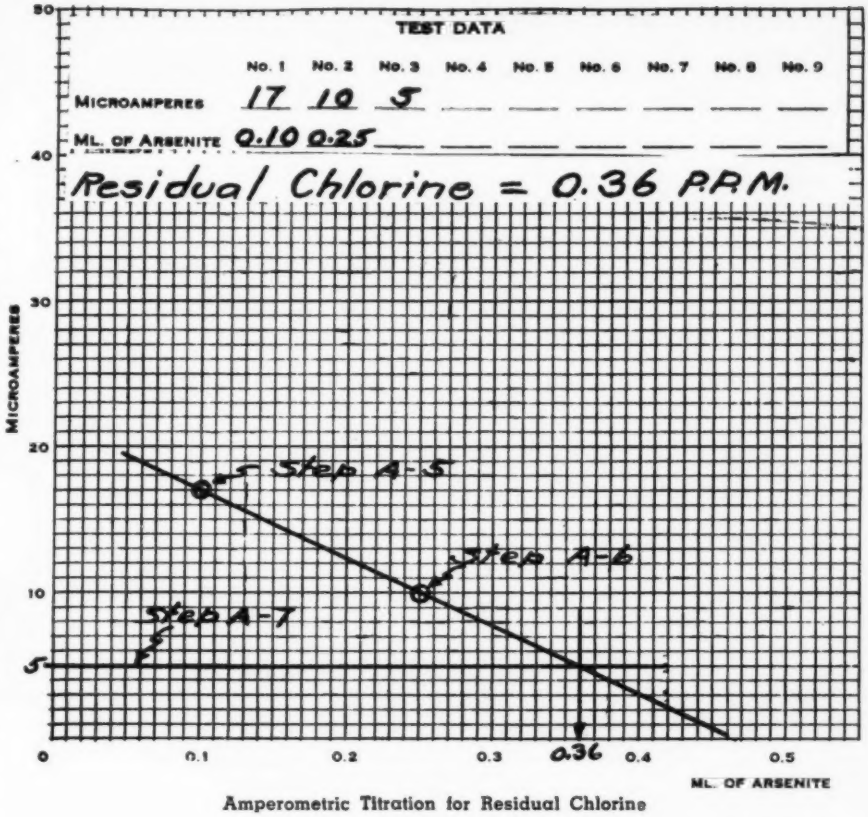
(3) *C.P. Potassium Iodide* (KI), fine crystals.

(4) *Zero Chlorine-Demand Water.*—To about 5 liters of distilled water, add enough chlorine water to obtain a dosage of about 5 ppm. of chlorine. Let stand overnight, then boil until all chlorine is removed. Cool and store in a clean, glass stoppered flask or bottle. Use immediately and discard what is left at the end of the day. If more is needed, prepare fresh.

(5) *Stock Arsenite Solution.*—Prepare 1 liter of 0.400 N Sodium Meta-arsenite solution or purchase it already prepared, from a laboratory supply house such as Fisher Scientific Co., of St. Louis, Mo., E. H. Sargent & Co., of Chicago, Ill., or others. Arsenite solutions of this strength are very stable and can be relied upon to hold their titer for at least one year.

(6) *Standard Arsenite Solution.*—Using an accurate 10 ml. pipette, graduated in 0.1 ml., measure out exactly 14.1 ml. of the Stock Arsenite solution, transfer it to a 1 liter volumetric flask and dilute to 1 liter with zero chlorine-demand water. Add 1 ml. of C. P. Chloroform and mix.

This solution is 0.00564 N and 1 ml. of it, when added to a 200 ml. water sample, is equivalent to 1 ppm. of residual chlorine. From this it can be seen that when this strength arsenite is used with a 200 ml. water sample, ml. of the arsenite reads directly in ppm. of chlorine. This solution should be made up fresh about every 4 to 5 days.


TEST DATA
No. 1 No. 2 No. 3 No. 4 No. 5 No. 6 No. 7 No. 8 No. 9
MICROAMPERES 17 10 5
ML. OF ARSENITE 0.10 0.25
Residual Chlorine = 0.36 P.P.M.
Step A-5
Step A-6
Step A-7
MICROAMPERES
ML. OF ARSENITE
0.36

Amperometric Titration for Residual Chlorine

Test Procedure

A. Free Residual Chlorine

1. Fill the silver-platinum electrode tube almost full with the saturated salt solution. The surface of the salt solution in the tube must always be higher than the surface of the water sample, so that salt solution will diffuse out through fritted section of tube.

2. Measure out 200 ml. of the water sample, pour into clean sample jar and place jar under stirrer.

3. Add 1 ml. of neutral buffer solution.

4. Start the stirrer. The microammeter needle will rise to some point above scale 0. (If the chlorine residual is very high, the needle will move completely to end of ammeter scale).

5. Using a 1 ml. volumetric pipette, graduated in 0.01 ml. intervals, *very* slowly add Standard Arsenite solution to sample until microammeter needle moves back down scale very slightly. Let needle come to a complete stop; then record both microammeter reading and volume of standard arsenite added to sample.

6. Repeat procedure in (5) above and again record microammeter reading and *total* volume of standard arsenite used. (The arsenite volume, in this case, is the total arsenite used in both (5) and (6).)

7. Add an excess of the standard arsenite (5 ml.) and when microammeter needle stops moving, record microammeter reading only. *Do not* record the arsenite volume.

8. Take an ordinary sheet of graph paper and mark off the vertical scale in microamperes from 0 to 20. Mark off the horizontal scale in ml. of standard arsenite from 0 to 1.0 ml. Use 0.01 ml. divisions.

9. On the graph sheet, plot the results obtained in (5) and (6) above, and draw a straight line through the two points plotted. Draw this line from one edge of the graph to the other edge.

10. On the vertical microampere scale, locate the microammeter reading determined in (7) above, and draw a horizontal line from this point until it intersects the line drawn in (9) above.

11. From this point of intersection, draw a line vertically down to the ml. of arsenite scale. The scale reading at this point is the ppm. of free chlorine in the sample.

(NOTE: In (5) above, if microammeter needle does not move back at all, when the arsenite solution is added, the sample does *not* contain any free chlorine, in which case proceed as in "B" below.)

B. Total Residual Chlorine

1. Proceed as in A (1), (2), and (3) above.

2. Add 1.5 grams of C.P. Potassium Iodide crystals. (This may cause the ammeter needle to jump around erratically and go to 0 on the scale, in which case, wait until needle again moves up the scale.)

3. Proceed as in A (4) to A (11).

4. The ml. of arsenite scale, this time, indicates total residual chlorine of the sample in ppm.

C. Combined Residual Chlorine

1. Subtract results in A (11) from results in B (11).

B minus A equals the ppm. Chloramine residual.

In the use of this method, two determinations, as in A (5) and A (6) above, will usually be sufficient to plot the line accurately, although more points may be determined and plotted if necessary. In the case of very low chlorine residuals, it is best to add very small increments of arsenite in order to prevent overstepping the end-point. Larger increments are more convenient when the chlorine residual is above 0.5 ppm.

D. Both Free and Combined Residual Chlorine

It is possible to determine both free and combined residual chlorine on the same sample, using this instrument in a slightly different manner, if the user desires. In this case, proceed as in A (1), (2) and (3). Start adding the standard arsenite in very small increments, waiting each time until the ammeter needle stops moving back, before adding the next increment of arsenite. Finally, a point will be reached where the last amount of arsenite added will fail to make the ammeter needle move. At this point, read the volume of arsenite used. This is the free chlorine residual in ppm.

At this point, add 1.5 grams of C.P. Potassium Iodide crystals to the same sample and continue as above, adding very small amounts of arsenite to the sample and watching the microammeter needle move back down the scale. When the last amount of arsenite added fails to make the needle move, record the amount of arsenite used in this last procedure. This value is the chloramine residual in ppm. The total volume of arsenite used in both procedures, is equal to the total residual chlorine in the sample.

From the above described procedure, it would seem that this method is much simpler than the one described earlier in the paper; however this is not the case. The first method given is more exact, in that the end-point of the test is calculated and does not have to be over-stepped in order to be found. In the case of high residuals, it takes a considerable amount of time to wait for the needle to stop moving each time, and the first method eliminates this difficulty.

In the Little Rock laboratory, a special printed form of graph paper is used, on which the vertical scale is graduated from 0 to 50 microamperes in 1 microampere divisions. The horizontal scale is graduated in ml. of standard arsenite from 0 to 1.0 ml., using 0.01 ml. divisions. Space at the top of the graph is provided for recording the individual test results. Fig. 3 shows one of these forms and the method used to plot results.

Summary

The determination of residual chlorine in water by amperometric titration with sodium arsenite in neutral solution, has been proven to be the most accurate method available at the present time, by several researchers [3] [5].

This procedure can be carried out by an apparatus which is fairly simple to construct, reasonable in cost, and which requires no calibration to use.

This method eliminates interference due to substances which interfere with other methods used to determine residual chlorine in water.

Acknowledgement

The author wishes to express his sincere appreciation to Dr. John F. Haller and Mr. S. S. Listek of the Mathieson Chemical Corp., without whose kind assistance this work would not have been possible.

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(4) Marks, H. C. and Glass, J. R., *J. of Am. Water Works Assn.*, 34: 1227 (1942)

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Tanghe Becomes Supt. of Water at Milwaukee

Edward F. Tanghe was made superintendent of the Milwaukee Water Dept. on March 28, 1949, as the result of an examination in which he stood as No. 1 amongst the seven city employees taking the test.

Mr. Tanghe is 57 years old and has been connected with the Milwaukee Water Dept. for 22 years. He became assistant superintendent in 1947, and had been serving as acting head of the department since the death of his predecessor, Herbert H. Brown, early this year.

Mr. Tanghe, a graduate of the Univ. of Wisconsin in 1914, for several years held the position of principal engineer of design and research in the Water Research Div. in the City Engineer's Office, prior to his appointment as Assistant Supt. of Water two years ago.

W. T. Ingram Joins N.Y. Univ. Staff

To Replace Dr. Rolf Eliassen

William T. Ingram has been appointed Associate Professor of Public Health Engineering at New York University, College of Engineering, effective May 1.

Professor Ingram has been engineering field associate for the Amer. Pub. Health Assn. for the past two and one-half years. During World War II, he was a Lt. Col. in the Sanitary Engineering Corps, where he served for five years. Prior to the war, Prof. Ingram was a municipal public health engineer with the San Joaquin Local Health District in Stockton, Calif.

A graduate of Stanford University in California with a Master of Public Health Degree from Johns Hopkins, Prof. Ingram has authored

many articles on public health engineering. He is a member of A.P.H.A., A.S.C.E., N.S.P.E., A.S.E.E., A.W.W.A., and F.S.W.A. among other technical organizations.

After July 1, Prof. Ingram will replace Dr. Rolf Eliassen as head of the Lewis V. Carpenter Sanitary Engineering Laboratories at New York Univ. Dr. Eliassen is leaving N.Y.U. to become head of the Sanitary Engineering Dept. of Mass. Institute of Technology, Cambridge, Mass.

PRINCIPAL REQUIREMENTS OF CATHODIC PROTECTION SYSTEMS*

by

FRANK E. DOLSON
Distribution Engineer
ST. LOUIS COUNTY WATER CO.
UNIVERSITY CITY, MO.

CATHODIC protection of steel water towers is a relatively recent adaptation of an old principle. Many years ago, in 1824 to be exact, Sir Humphrey Davy discovered and applied this principle for protecting under-water metal parts of ships against salt water corrosion. He utilized a *zinc-copper* couple for replacing corrosion of copper with corrosion of zinc. Some twenty years ago, the need for protecting long transmission pipe lines, (from soil corrosion) became apparent and the oil and gas industries, recognizing the economies of cathodic protection, made extensive use of it in a successful effort to prevent service interruptions.

The water works industry also accepted cathodic protection as an effective and economical method for preventing corrosion in water tanks. Perhaps because this process seemed an easy answer to a very difficult maintenance problem, many of us hasten to make use of it without first exercising prudent engineering precaution. As a result, many cathodic protection systems were purchased which provided either partial protection or no protection at all. Some of the initial systems were underdesigned with inadequate rectifier capacity, while others were sold with one of the necessary parts missing.

This paper will discuss some operating experiences with cathodic protection installations as well as costs and economy. Obviously there is no economy in purchasing a system that does only a portion of the job. No doubt many water works superintendents and operators have asked themselves questions such as these.

1. Do I need cathodic protection?
2. Is it economical?
3. How can I tell whether it is doing the job?

Perhaps the following discussion will be of some value in answering these questions.

*A paper presented before the Missouri Sect. of A.W.W.A. and here published by permission of the Association.

Corrosion of Steel

The surface of steel in contact with soil or water tends to become either anodic or cathodic. For example, a new section of steel pipe connected to an old section of badly corroded pipe will immediately become anodic to the old section. A rusty piece of steel and a bright piece of steel placed in water and connected together with an external wire will form a corrosion couple. The bright piece of steel will be anodic to the rusty piece of steel. So it is in a water tank.

In a new unpainted tank the mill scale coating on the steel will be cathodic to bright sections of metal through exposed holidays in the mill scale. In a case such as this, there would be a vast cathodic area and many small anodic areas. In a corrosive water this would be conducive to rapid localized corrosion. Abrasions of the metal surface, caused for instance, by movement of ice would result in these areas being anodic to all the tubercles that may have formed on the inner surface of the tank. Current in this case would flow from the bright metal through the water to the rusty metal and then complete its circuit through the sides of the tank.

Dry Cell

The principle of the common dry cell is an excellent analogy for describing the corrosion process. All of us are familiar with the uses of this very necessary piece of equipment and most of us are familiar with its principle. A dry cell consists of three essential parts, namely: a carbon cathode, a zinc anode, and the intervening electrolyte. The carbon cathode is marked "plus" and the zinc anode is marked "minus." This conforms to the accepted practice in determining the direction of current flow. When a resistance load is connected across these two terminals, current flows from the positive terminal through the load thence to the negative terminal which is the outer zinc shell of the battery. From the zinc terminal current flows through the electrolyte to the carbon cathode which completes the circuit. The zinc in this case is an anode and progressively deteriorates as the battery is used. The current flow in the external circuit is from the carbon to the zinc. In the internal circuit the flow of current is from the zinc to the carbon or from the anode to the cathode.

Corrosion of a steel water tank can be compared to a dry cell. There are a great many of these little batteries formed in a water tank. Each one is generating a small voltage. Each one is causing minute quantities of current flow. Each one, with adequate oxygen supply, is causing corrosion.

Cathodic protection in effect simply superimposes another current upon these many little battery cells. It has been found that when current entering the corroding area is sufficiently strong to counterbalance the current of these many battery cells, corrosion will cease. Current from the C.P. system must be equal to or greater than the current leaving the many corroding or anodic areas.

Current Required

Now comes the problem of how to determine the current density, i.e., the current per square foot of tank, required to prevent corrosion. The component parts of a C.P. system consist of:

1. A source of power—generally a full wave rectifier connected to a multiple tap transformer.
2. An anode system.
3. Necessary electrical wiring to connect the anode system to the rectifier.
4. An electrolyte.
5. The metal surface to be protected.
6. An electrical path to return the current from the protected metal to the rectifier.

In operation current flows from the rectifier unit to the anode system, thence through the water or electrolyte to the protected metal surface. In tanks, the circuit is completed by using the tank as a conductor to return the current to the rectifier.

The total current required to prevent corrosion in the tank is difficult

to determine. If the entire tank were bare it would be an easy matter to experimentally determine in a laboratory the current density necessary to prevent corrosion in the test piece. Then, knowing the total area of the interior surface of the tank, it would be simple to determine the capacity of the rectifier. The voltage requirement on the rectifier could likewise be determined, knowing the various resistances involved. However, in the field it is not quite so easy since most tanks have either a coating of paint or some other protective covering or else the surface is partially, at least, covered with rust. The surface of the steel effectively insulated from the water does not need cathodic protection. In most cases tubercles and rust have formed the cathodic portion of a local action cell and therefore are not initially in need of protection. The areas to be protected are simply those areas that are anodic.

In a bare steel tank, assuming that a current density of 2 milli-ampere per square foot would stop corrosion, a rectifier capacity of 2 amperes would be required for each 1000 square feet of metal surface to be protected. However, if this metal surface had originally been painted or covered with a protective coating of adequate insulating value it is quite possible that 75 per cent of the metal would not require protection. In such a case protection of the entire surface could be obtained by providing ½ ampere or ¼ of that required to protect 1000 square feet of bare metal.

It would seem, therefore, that in designing the cathodic protection unit there are three major unknowns:

1. Current density required to protect the metal against corrosion in a particular water.
2. The amount of surface to be protected; that is, the entire area minus that portion that is effectively coated.
3. Distribution of the protecting current.

The first unknown can be readily obtained in the laboratory by a simple experiment. The second and third unknowns can only be solved in the field by measuring the voltage effect of the rectifier at the surface of the corroding metal. Generally this is done by measuring the voltage difference between the metal and water.

Description of Installation

I should like to describe a cathodic protection installation which we have on a 250,000 gal. elevated water tank. This tank was constructed in 1934, being 40 ft. in diameter and 85 ft. high. The water depth in the elevated bowl is 29 ft. and the riser pipe is 5 ft. in diameter by 55 ft. high. The tank mill scale was undisturbed until after erection. The surface of the steel was then cleaned by scraping and brushing, after which two coats of red lead were applied. A cathodic protection installation was installed in this tank in 1940. The original cathodic protection system consisted of a 2-ampere rectifier and three ⅝-in. anodes. The rectifier was later replaced with a 3-ampere, 27-volt unit, and an additional anode was installed in the riser pipe. The current output was distributed in the proportion of 1¾ amperes to the tank and ¾ ampere to the riser pipe. The current densities were respectively 0.46 and 0.86 milliamperes per square foot to the tank and riser, based on the assumption that the entire surface was bare. The voltage setting was approximately 8 to 10 volts and the water resistance was 3900 ohms per cubic centimeter. The indicated resistance of the entire circuit was approximately 3.3 ohms.

In an effort to determine the effectiveness of this installation a series of voltage readings were obtained. At the time of this test one of the three anode rods was damaged to the extent that only about 5 feet of the rod was in contact with the water. The other rods were in good condition although misshapen. A copper sulphate electrode was lowered into the water opposite an anode and very close to the water surface near the tank wall. The electrode was equipped with spacers in order to keep it within one inch of the metal surface. A potentiometer was then connected between the tank and the copper sulphate electrode. With the rectifier turned off a reading of approximately 0.45 volts was obtained. With the rectifier turned on, a reading of approximately 0.55 volts was obtained.

In other words the metal was rendered 1/10th of a volt more negative by the use of this cathodic protection system. A series of voltage readings was then obtained at various locations along the tank surface directly below the original test. In each case the readings were the same. No attempt was made to obtain similar readings in the riser pipe.

What Readings Indicated

The inference from these readings would be that the metal in this tank was receiving only partial protection against corrosion. The question then arises what voltage reading is required to indicate full cathodic protection. A safe criterion to follow is 3/10ths of a volt since the voltage generated by the many corrosion cells existing on the tank surface is generally considerably less than this figure.

The problem of current distribution from a cathodic protection installation can be determined very easily by using voltage readings. Consider for a moment a steel tank that is perfectly insulated from the water with a good electrical coating. This tank does not need cathodic protection because the steel is not in contact with the water.

Now consider that one square foot of this tank was scraped down to bare metal and exposed to corrosion. In this case it would be necessary to provide only enough current to protect one square foot of metal. As the coating on a tank deteriorates due to many causes, breaks or holidays in the coating occur. How many or the distribution of such breaks is unknown. No amount of laboratory work can reveal the interior condition of a specific tank. It is possible, however, by the use of voltage readings to determine, after a cathodic protection installation has been installed, the current distribution.

To be absolutely accurate the method outlined above should be corrected for I.R. drop through the water and metal coating. However, for practical purposes it will indicate whether or not the C.P. system is effective.

Inventory of Water & Sewage Facilities Available

According to Mark D. Hollis, Chief of Engineering Activities of the Public Health Service, more than 900 copies of the recently published "Inventory of Water and Sewage Facilities in the U.S." have been distributed since it became available. Most of these have gone to state health departments and other public and private organizations interested in environmental health.

This inventory was the first complete listing of communities and their sanitary facilities, including those without such facilities. Prepared by the Environmental Health Center of the U.S.P.H.S. at Cincinnati, in cooperation with state sanitary engineering departments, this inventory includes details on sources of water, type of water treatment plant, and methods of treating sewage.

Copies of the inventory may be obtained on request from the Officer in Charge, Environmental Health Center, Public Health Service, 1016 Broadway, Cincinnati 2, Ohio.

CATHODIC PROTECTION EQUIPMENT*

Capacities, Performance and Costs

by

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THE application of cathodic protection is becoming more and more important as a means of fighting corrosion on pipe lines, elevated steel water tanks, refinery equipment, and other metallic structures in contact with water or soil. As the corrosion of submerged metal is caused by small currents flowing from anodic to cathodic areas, cathodic protection stifles the flow of current in these local "corrosion cells" by furnishing an auxiliary current from anodes suspended in water to the tank and riser plates.

Auxiliary current is furnished by the following sources: (a) Rectifiers are used where power is available. They have the advantage of being easily regulated, with no moving parts, and require very little maintenance. Copper oxide and selenium stacks are the types generally used and have proven satisfactory in our field use for over twelve years. (b) Galvanic anodes of magnesium or zinc are used extensively for pipe line protection, especially. Other problems can be met with this type of anode provided current density requirements are not too high.

Several experimental installations have been made in elevated steel water tanks with magnesium rod. Cathodic protection with galvanic magnesium anodes is used quite extensively in domestic hot water heaters, and most manufacturers now include this protection in their product.

Anode Material

After selection of power source, the next problem is that of choosing anode material. We have found that anode material should have the following properties: (a) strength, (b) a high electro-chemical equivalent, (c) an even pattern of corrosion on its surface and (d) suitable shape. Some metals chosen for anode use are aluminum, steel, carbon, and platinum. Galvanic anodes are usually magnesium or zinc. In protecting elevated steel tanks, we have found the use of aluminum anodes to be satisfactory with rectifiers as the power source. The aluminum is light in weight, has a high electro-chemical equivalent, a uniform corroding characteristic, and competes favorably with other metals economically. Steel discolors the water around the electrode and disintegrates at the rate of some 20 lbs. per ampere year as against 6.4 lbs. per ampere year with aluminum. Carbon is fairly brittle and platinum, although theoretically non-sacrificial, is expensive since equivalent lengths and number of platinum anodes are necessary to obtain proper current distribution. In the case of galvanic anodes, magnesium has the advantage of a higher driving potential and a higher electro-chemical equivalent than zinc.

Coatings have been employed for many years as a protective measure against corrosion. They can be effectively used with cathodic protection since the exposed areas are reduced to holidays or breaks in the coating which may only represent a small percentage of the total surface. Coatings of high electrical resistance are best because they force protective currents to seek out these breaks or holidays. In the interests of lower costs of installation and operation, it is advisable to paint water contact areas of new tanks and riser pipes before applying cathodic protection. In old tanks, the old paint and corrosion products are useful in reducing current density demand and repainting is seldom recommended before installing cathodic protection.

Design Factors

In designing a cathodic protection system, the engineer must consider the following factors affecting rectifier capacity and anode design: (a) area of bare metal exposed to corrosion, (b) water analysis, (c) operating conditions, (d) configuration of structure to be protected, and (e) obstructions such as structural members present. To elaborate briefly, water or soil analysis is important as it reflects on current density required for protection and anode configuration. In waters of high oxygen content, or other depolarizing compounds, the current density required for protection is greatly increased.

Current density required varies over a large range. Some tanks need only 0.5 milliamperes per square foot for protection while others may need as much as 50.0 milliamperes per square foot. It is necessary to know the resistance of the water as this affects the number of electrodes and their spacing. A water of high electrical resistance may need electrodes spaced within six inches from the tank wall and twelve inches apart, while in waters of low resistance, one electrode spaced centrally may do the work. In designing, electrodes must be spaced so that all submerged sections of the tank are adequately protected. A separate electrode must be installed in steel riser pipes as very little current supplied by bowl electrodes reaches the riser sections of the tank. Also, if the tank is very large it may be necessary to locate anodes to take care of the bowl floor as electrodes set to take care of side walls may be too far away. Obstructions, such as heater or overflow pipes or structural members need protection also and may require specially spaced electrodes.

Although the cathodic protection system requires a minimum of attention, it should be regularly checked so that continuous operation is obtained within the specified current range. As the anode material disintegrates, the resistance of the circuit is increased requiring a simple adjustment of the transformer taps on the unit. Anode material is easily replaced after its depletion.

In cleaning sediment or old paint and old corrosion products from a tank under cathodic protection, the inside may be swept out with brooms and flushed with a hose. The surface should not be wire brushed or scraped as current density requirements may be markedly increased by exposing bare metal.

Costs

The cost of a cathodic protection installation on a tank is comparable to the cost of one complete scraping and painting of the tank interior.

Cathodic protection properly applied can add many many years of trouble-free service to tanks, and eliminate the costs and outages of tank service incident to draining, cleaning, repairing and painting.

*A paper presented before the Missouri Section of A.W.W.A. and here published by permission of the Association.

MECHANIZATION OF WATER UTILITY OPERATIONS*

by

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Fig. 1—Jeep-Mounted Trenching Equipment

THE increase of interest in mechanization at this time has been brought about by economic factors within the past few years. The upheaval caused by World War II, resulting in the all-too-well-known manpower and material shortages and subsequent tremendous increases in costs of operation, has made it difficult to maintain satisfactory service at reasonable cost. The inflationary pressures since the end of hostilities have been of such magnitude that it is not necessary to do more than cite them as the factors underlying the necessity for considering mechanization, or improvements in existing mechanized operation, of every phase of work. Another factor stressing the need for mechanization is the difficulty in today's labor market of replacing retiring older men with younger people of equal diligence.

As the cost of mechanization is sometimes very high, a thorough study must be made of the expense involved and this must be balanced against the probable savings which may accrue as a result of a change in procedure. The greatest danger in this problem is that of mechanizing operations which do not occur with sufficient frequency to justify the cost. For example, a certain plant, in submitting an inventory of equipment, listed a large-size tapping machine with the notation that the unit was in excellent condition—having been used only twice in the past twelve years. Obviously, the purchase of this equipment was not justified.

The problem of water utility mechanization, touching as it does practically every operation, is so vast that this paper will discuss only briefly some of the labor-saving devices which have been placed in use or are at present contemplated. Most of the items mentioned apply primarily to the distribution system. The mechanical handling of coal, ashes and chemicals is a specialized matter, depending upon local conditions, as is automatic pumping station operation. For this reason, neither of these subjects will be taken up.

Needless to say, not all companies can justify the purchase of the equipment described. An attempt will be made, therefore, to show the possible savings in time and labor effected by means of each piece of equipment, as well as its approximate price, if this information is available. Naturally, the frequency of operation will be the yardstick in determining the advisability of purchasing a piece of equipment.

Mechanical Trenching Equipment

For sheer energy expended, the most extensive operation in the water utility business is the excavation for additions to, and the maintenance of facilities in, the distribution system. Although trenching machines of various designs have been used extensively in the past for the installation of water mains, hydrants and the like, much of the necessary excavating work is done by manual labor. There is a great need for suitable mechanical or semi-mechanical tools to handle the various excavations encountered.

For the past year use has been made of a new type of trenching machine, first put on the market within the last eighteen months, which reduces materially the manual work involved in excavations for installing small-diameter pipe. This particular unit is mounted on a Willys-Overland jeep with four-wheel drive. The trenching equipment consists of a long boom to which is attached a rotary chain with cutting teeth spaced at intervals on the chain linkage (Fig. 1 and 2). Cutting teeth are available to excavate narrow trenches from 6 to 10 in. in width for a maximum depth of 5 ft. The entire trenching unit is driven by the jeep engine through a power takeoff connection. The mobility of this unit, driven like an ordinary truck, facilitates many small-diameter main extension and service installations which cannot be made economically with large-size trenching equipment. Once on the site of the job, this small trenching unit can be placed in operation in approximately five minutes. Some difficulty has been experienced with maintenance of the unit and several structural weaknesses have already been overcome. In general, however, the unit should be used only where soil conditions are not severe. Actual records indicate the successful use of this equipment in excavating the necessary trenches for 2-in. cast-iron main extensions. Table 1 lists seven jobs completed in one month. A total of 1,755 ft. was excavated in eighteen hours, averaging approximately 100 ft. an hour. The work contract stipulated a rate of 20¢ a foot for excavation and 5¢ a foot for backfilling. The backfilling was done by a snow plow attachment on the front end of the jeep.

TABLE I

Efficiency of Trenching Equipment

Trench Length ft.	Character of Soil	Digging Rate fpm.
280	good	2.43
360	muddy	2.40
165	very good	2.75
270	hard	1.80
235	muddy	1.30
210	muddy	1.55
235	iron slag and rock fill	0.65

Other contracts have been let for service excavations in new real estate developments at the same rate. This arrangement

Fig. 2—Jeep-Mounted Trencher in Action

*Reprinted from *J.A.W.W.A.*, 41, 97-104 (1949).

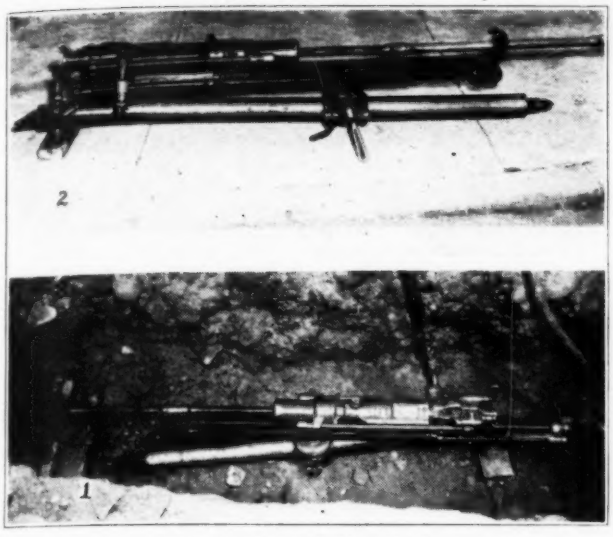

Fig. 3—Top—Drifter Drill.
Fig. 4—Bottom—Drifter Drill Installation

has worked out satisfactorily because the work is done before any street paving, curbs or sidewalks are laid.

At present consideration is being given to the possibility of using one of these units equipped with cutters for a 10-in. trench to install 6-in. cast-iron water mains. As the pipe is being used in 18-ft. lengths, it is planned to make up one joint above-ground and lower the resulting 36-ft. section into the trench. This procedure would require digging bellholes only every 36 ft. and may result in a substantial saving, as compared with the use of a large-size trenching machine. Approximately 75 per cent of the required excavation for bellholes can be done by having the machine dig short parallel trenches at the bellhole locations, leaving only a narrow bridge wall between.

A very successful experimental installation of 6-in. asbestos-cement pipe was made less than a month ago. This particular extension was 365 ft. in length and involved installing a 6 x 6-in. tapping sleeve and valve and tunnelling under a two-lane concrete road. The rest of the trench was dug and backfilled by the jeep. The asbestos-cement pipe was made up on stringers across the ditch and was progressively lowered in place by rope slings. The total installed cost, less material, was 73¢ a foot. The authors are confident that with only a slight improvement in procedure, 6-in. asbestos-cement pipe can normally be installed for approximately 50¢ a foot under favorable soil conditions. The jeep-mounted trenching machine has definite possibilities when good judgment is used in selecting the proper spot for it.

Drifter Drills

The installation of service lines under pavement has always been a most expensive operation. Moreover, there is an ever present safety hazard due to restricting traffic to one side of the road. Likewise, the broken springs and poor public relations caused by sunken ditches across the road are not pleasant to contemplate.

For a great many years various types of pipe-pushing machines have been employed, but the difficulties encountered when stones or other obstructions cause the drive point to be deflected have often resulted in the abandonment or serious curtailment of the use of this equipment. Because of this experience, experiments were made with an air-operated drifter drill which has long been used in mining (Fig. 3 and 4). The results obtained were so satisfactory that the drills were purchased for fourteen of the larger American Water Works Co. subsidiaries which have a sufficient amount of service installation work to justify the cost.

In using this machine, a trench 7 ft. long is excavated in the curb or sidewalk area, and the drifter drill is placed in this opening, mounted on an air column. The drillhole is then made underneath the pavement, by means of a jack bit and coupled steel, to a small opening at the main. When the drilling is completed, the jack bit is removed and the service pipe attached to the rod and drawn through the hole, while the rods are extracted by the drifter.

This method has been over 90 per cent successful in all types of soil formation, from sand to hard rock. More than 2,000 service installations have been made, with lengths up to 50 ft. Much of the development work on the adaptation of the drifter drill has been done at Summit, N.J., where ground formations are very severe. Table 2 shows the average times for drilling services through various types of soil formation at Summit.

A cost comparison is available for only one plant to date. In 1946 this company installed 1,619 new ¾- and 1-in. copper services with an average length of 15.5 ft. at an average labor cost of $26.06 per service. In 1947, 2,505 new ¾- and 1-in. copper services were installed with the drifter drill application, the only known change in operating procedure. The average length of a service in 1947 was 15.6 ft. and the average labor cost per service was $22.90. Wage rates were 10 per cent higher in 1947 than in 1946, so that a conservative estimate of the savings effected by using drifter drills would be in the neighborhood of $12,500. It is evident, therefore, that the company's investment of $2,600 for two drifter drills has been amply justified. The saving in street paving charges is an unknown quantity, but the number of installations which are possible with the drifter drill, and which could not otherwise be made except by excavating the entire trench manually, indicate a substantial decrease in this expense.

Under average soil conditions, a 105-cfm. air compressor is satisfactory. For use in all types of soil, however, nothing less than a 160-cfm.—and preferably a 210-cfm.—compressor should be selected.

TABLE II
Drifter Drill Operation

Drive Length ft.	Soil Formation	Time hr.
17	hard clay and boulders	2
23	hard clay	2
18	clay	¼
20	solid rock	5
30	trap rock	3
30	loose gravel	8
30	shale rock	1

The cost of a drifter drill, with rods and accessories, is $1,300 A 105-cfm. trailer-mount compressor is priced at $2,855 and a 210-cfm. skid-mount compressor, at $4,555.

The portability necessary in a compressor for this work is satisfactorily provided by the 105-cfm. two-wheel trailer mount, but, as 210-cfm. compressors are mounted on four wheels for trailer carry, the skid mount on a two-ton truck is believed preferable.

Truck Body Design

The most important units in a water utility are the employees. It is therefore necessary to make working conditions as pleasant as possible by providing tools that will enable the work to be done in the easiest manner, clothes for extreme weather conditions and proper riding comfort from job to job. Men should

Fig. 5—All-Purpose Truck

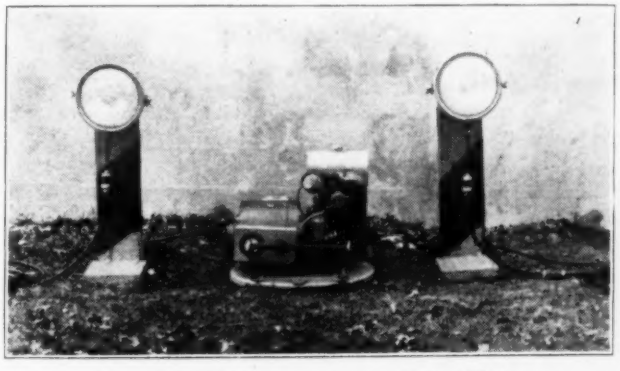

Fig. 6—Portable Generator and Floodlights

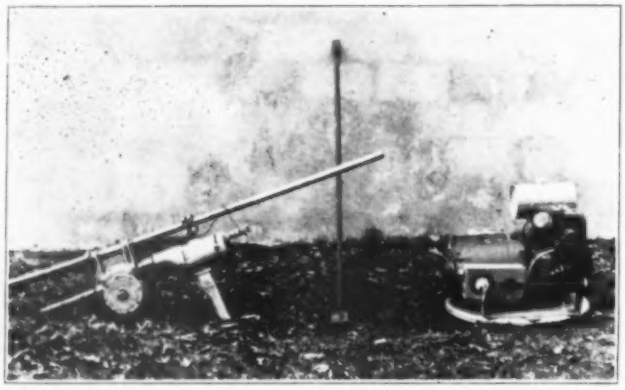

Fig. 7—Power Wrench Operated by Electric Drill

not be transported on a wooden plank in the back of a truck loaded with picks, shovels, bars, pumps and pipe. Consequently, one of the first requirements in truck design is a crew cab.

The next item of importance in an all-purpose truck is lifting equipment. Proper mechanical means for lifting heavy objects, such as fire hydrants, result in easier working conditions, lower manpower requirements on the job and a reduction in accident hazards. For this purpose, it is useful to have a winch mounted in the truck working from a power takeoff, and removable stiff legs for the back of the truck.

Next, the truck must contain sufficient accessible storage space for numerous small fittings, a tapping machine, accessories, boots, and the like which should be carried. Furthermore, loading space should be provided for pipe, fittings and pumps for repair jobs, and everything should be enclosed against the weather.

Because no ready-made body could be found containing all these features, a body was designed which is suitable for mounting on a standard two-ton cab-over-the-engine truck (Fig. 5). The crew cab is in the front of the body, with the winch located under the seat. Plenty of cabinet storage space is provided on each side of the body and there is sufficient loading room between the cabinets. Removable stiff legs work off the back of the truck. In addition, the rear half of the top slides forward for loading from overhead hoppers. The body can be transferred easily to a new truck when the old one is traded in, and no special design is necessary in purchasing a new truck. The cost of the body, winch, stiff legs, cable, power takeoff and mounting is $3,500.

Some of the American Water Works Co. subsidiaries are using a hydraulically operated hoist of one-ton capacity, mounted at the right rear corner of the truck body, to perform the necessary lifting and lowering operations normally encountered in distribution system work. The hoist has one disadvantage, as it is not possible to lower an object from the truck body to the bottom of the trench in one operation. It is necessary to lower pipe or fittings to the ground, or on planks across the ditch, and use a longer sling from this point to the bottom of the trench. The difficulty is not serious, however, and the unit has been very popular with the workmen. The cost of this unit installed is $370.

A floorstand model of the hoist is also being used in a large meter shop. This unit is on wheels and is very practical for handling large meters.

Night Lighting

For night and emergency lighting, a portable generator driven by a gasoline engine is recommended, together with floodlights and the necessary attachments (see Fig. 6). A 1,500-w. machine at 115 v., though rather large for floodlights, was selected because it was desired to operate other equipment, described below, along with the floodlights.

In night emergency work, poor light not only slows the job but also makes for a high accident rate. These deficiencies may be overcome by means of floodlights. The generator, three floodlights and accessories cost approximately $460.

Valve-Turning Operations

It was desired to obtain a piece of equipment for operating large valves which could easily be set up regardless of the valve location or a tilt to the valve box and which would least tend to break a stem. Consideration was given to both air-operated and electrically powered wrenches. The most promising arrangement found was the power wrench operated by means of a ¾-in. heavy-duty electric drill (Fig. 7). Power for the drill is furnished by a portable generator.

With this machine a 24-in. valve, requiring 225 turns, was operated by two men in nineteen minutes. The best previous time for this valve was 1½ hours with six men, four operating the valve and two spelling. Furthermore, after operating the valve by hand, the six men were pretty well spent, while very little effort was expended by the two men using the power wrench. This method does not cause the feel of the valve to be lost. As operation becomes difficult, force is put on the wrench, which is felt by the two men holding the handles who run the valve back a few turns when necessary, as in hand operation. There is a steady strain on the valve, which diminishes the possibility of breaking a stem.

The generator, drill and power wrench are also used to mechanize the operation of large tapping machines for wet cuts. Two men can make a 6 x 6-in. cut in about 30 minutes with little physical effort.

Although the power wrench could be run by an air motor, the extra expense does not appear warranted. Moreover, it is not advisable to tie up an air compressor for this work. The more uses found for a piece of equipment, the better. A machine earns no money sitting in the shop.

The approximate cost of the power wrench, drill, valve key and adapters is approximately $285.

Pipe Finders and Leak Locators

No company which can afford a pipe finder and leak locator should be without them. The importance and labor-saving advantage of being able to trace pipelines in the ground is well known to every water works operator. A machine should be obtained which will work by energizing the pipe directly and which can also be used without a direct connection. Many situations will be encountered where one or the other method will give better results.

Excavating for a leak and missing its location is not only disappointing but also expensive, especially when pavement is involved. This trouble can be overcome by the purchase and intelligent utilization of a good leak-locating machine (see Fig. 8). In buying such equipment, one should bear in mind its use for making a leak survey. The approximate cost of a leak locator is $425. A pipe finder can be obtained for about $200.

Painting Fire Hydrants

Many companies have paint spray equipment for maintaining pumping station and purification plant buildings. Plans are being made to paint fire hydrants with this equipment, using a semi-circular shield to protect pedestrians and nearby objects and painting one half of the hydrant at a time. Even if a small portable generator and a spray gun had to be purchased especially for this work, a large number of companies could readily justify the investment for this purpose alone.

Large Outdoor Meter Settings

The American Water Works Co. has a standard meter piping system for large meter settings. Installations requiring a capacity larger than that of a single 2-in. disc meter are so arranged that, with certain changes, batteries of two or three 2-in. disc meters, a 4-in. current type meter with a 2-in. bypass or a battery of two 4-in. current meters can readily be connected. Consideration is being given to prefabricating the standardized piping and meter vaults for these large installations. One manufacturer is now engaged in a study of a packaged piping design suitable for the company's standard installation, and the cost of this work may be materially reduced in the near future.

Radio-Telephone Communication

The use of radio-telephone communication between the office and the company trucks and cars has been found very expensive. Certain telephone companies offer a so-called "signaling service" which presents, at much reduced cost, a means of

Fig. 8—Leak Locator

locating workmen in an emergency or when it is desired to issue instructions. Instead of having a telephone for two-way service, an audible and visual signal is given to the truck or trucks carrying the receiving equipment. Upon receipt of the signal, the employee goes immediately to a regular telephone and calls the office for the message. If the driver is in or near the truck, he of course hears the bell ring. If he is not where he can hear the signal, he observes the light upon his return. The monthly charge for one of these units employed in a truck at Wichita, Kan., has not exceeded $16.00. A unit charge of $12.50 allows 40 signals per month, with extra signals at the rate of 10¢ each. Certainly a company which serves a large territory should seriously consider using this service.

Distance-Measuring Wheels

Field survey work for proposed extensions is materially reduced when distance-measuring wheels are used in place of the ordinary 100-ft. tape. These wheels are sufficiently accurate for most field work encountered, and measurements can be made by one person instead of the usual two. The cost of approximately $100 is quickly repaid if extensive work of this nature is required. These wheels are in use at a number of the company's larger plants and have been found indispensable.

Motor Scooters

A three-wheel motor scooter with service box was recently acquired by an American Water Works Co. subsidiary for the use of its meter readers. Additional transportation equipment had been deemed necessary to keep up with the work. Study indicated, however, that a large portion of the time of one truck was taken up for reading scattered meters in outlying districts and for changing meters. Neither of these operations requires the use of a truck, yet some means of transportation had to be available. The small motor scooter has proved to be well suited for this purpose during clear weather. As other demands for transportation are curtailed during periods of inclement weather, trucks are at hand for reading and changing meters when needed. Approximately $1,200 was saved in the purchase price, and the cost of operation will be materially less than for a truck.

Conclusion

This paper has attempted to show that there is a need for mechanization and has pointed out a few of the items available to start a mechanized program. One very important point should be stressed: a machine will not operate without human direction. The work a machine will accomplish and the amount of maintenance it will require depend on the judgment and skill of the operator. There are not too many people in the average distribution system forces who are able to handle mechanized equipment properly. Therefore, mechanization will open a field for skilled help in this department.

Fewer and better men, with proper equipment, will maintain good standards of service economically in spite of the scarcity and high cost of labor.

N.Y. State Passes Stream Pollution Control Law

The State of New York Legislature has enacted a law to amend the Public Health Law and provide for control, prevention, and abatement of pollution in the waters of the state. Thus the State of New York has joined the growing list of states which have enacted laws to abate pollution.

In addition to defining wastes and waters, the new act creates a Water Pollution Control Board composed of commissioners of the Dept. of Health, Dept. of Conservation, Dept. of Agricultural Markets, Dept. of Commerce, and the Supt. of the Dept. of Public Works.

The Board will appoint an executive secretary who is to administer all of its water pollution control activities.

The Board is authorized to adopt classifications of waters and standards of quality and purity thereof, all public hearings to make orders requiring discontinuance of discharge of wastes, and to issue permits for waste disposal.

According to the new act, the classification of water and adoption of standards will be flexible to apply to the various waters in the state and the uses to which they are put.

Provisions are made for public hearings and for penalties in cases of violation. Operation of the Stream Pollution Control Board, as to its technical provisions, will be within the State Dept. of Health, and there will be a mobile pollution laboratory which is to be a part of the program.

Scott Johnson Succumbs to Heart Attack

W. Scott Johnson & Mrs. Johnson

Photographed Oct. 26, 1948, on the occasion of presentation of mementos to Mr. Johnson by the Missouri Water & Sewage Conference and Missouri Section of A.W.W.A. in recognition of 25 years of Public Health Service and the founding of the Missouri Conference in 1925.

W. Scott Johnson, Director, Section of Environmental Sanitation, Division of Health of Missouri, passed away at his home in Jefferson City on March 13, 1949, as the result of a heart attack. He had been enjoying the best of health until stricken.

W. Scott Johnson was born June 2, 1896, in Emporia, Kansas. He obtained degrees of Bachelor of Science in Biology and in Civil Engineering at the University of Kansas and a degree of Master of Science in Engineering at Harvard University.

He had attained wide recognition in his profession, having been recently honored for his achievements during 25 years of public health engineering in Missouri. He was a past chairman of the Engineering Section of the American Public Health Association; and a past chairman of the Conference of State Sanitary Engineers. He was a member of the American Society of Civil Engineers, American Water Works Association, Missouri Society of Professional Engineers, and the highly appreciated Missouri Water and Sewerage Conference, which he founded to serve the water and sewage works operators of Missouri.

Rainfall and Runoff

"RAINFALL AND RUNOFF," by E. E. Foster is the first book published in 20 years on the subject. Mr. Foster is Senior Engr., U.S. Bureau of Reclamation, Denver Federal Center. Of particular interest to hydrologists, hydraulic engineers, sanitary engineers, and others in the field of water and sewage works, this new book contains information on important new methods of hydrologic investigation and analysis, sample data, and charts and diagrams, etc. on rainfall and floods.

The book contains 12 chapters covering the following: Field of Hydrology, Atmospheric Moisture and its Precipitation, Air Masses, Storms, Distribution of Precipitation, Frequency of Precipitation, Evaporation, Snow, Runoff, Floods, Ground Water, and Utilization of Hydrologic Data.

"Rainfall and Runoff" is published by the MacMillan Co., 60 Fifth Ave., New York 11, N.Y., contains 487 pages and retails at $9.00 a copy.

TIPS ON BACKWASHING OF ION EXCHANGERS*

by

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The Resinous Products and Chemical Co.

PHILADELPHIA, PA.

EFFECTIVE backwashing maintains ion exchange resin units at peak capacity by keeping the resin particles clean. To this end, the following tips are offered to help water works men and others to whom water softening or deionization is a vital process.

In backwashing, as in the case of sand filters, the rate of up-flow of water through the exchange bed should be such that the bed expansion is at least 50 per cent. With this expansion, the particles are scrubbed; the bed is freed of contaminants; and the resin particles are reclassified so that the larger particles are found at the bottom of the bed. The expansion of the resin bed during backwash eliminates channeling or packing which may cause reduction in operating efficiency.

Effect of Temperature

Temperatures of the backwash water is an important factor governing bed expansion which is overlooked most frequently. Fig. 1 shows how bed expansion depends on temperature and flow rate for the *cation* exchanger, Amberlite IR-100. This chart illustrates the problem of the operator of an installation where a pump rated to deliver 5 gallons per square foot of bed area per minute at 60° F was used at 125° F. The bed expansion of 18 per cent which resulted was insufficient. It could be raised to the desired 50 per cent only by installing a new pump that could deliver the necessary 9 gallons per square foot per minute at the higher operating temperature.

The backwash characteristics of the exhausted *anion* exchanger, Amberlite IR-4B, are pictured in Fig. 2. Since some applications may require backwashing of the resin bed before it is completely exhausted, Fig. 3 presents the data for the regenerated form of the resin. Because of the lower density and smaller size of the regenerated resin, much lower flow rates are needed to obtain the desired expansion.

*Extracted from the exhaustive and overall treatise on "Practical Aspects of Deionization" presented by Messrs. Thompson and McGarvey before the Eighth Annual Water Conference of the Engineers' Society of Western Penna.

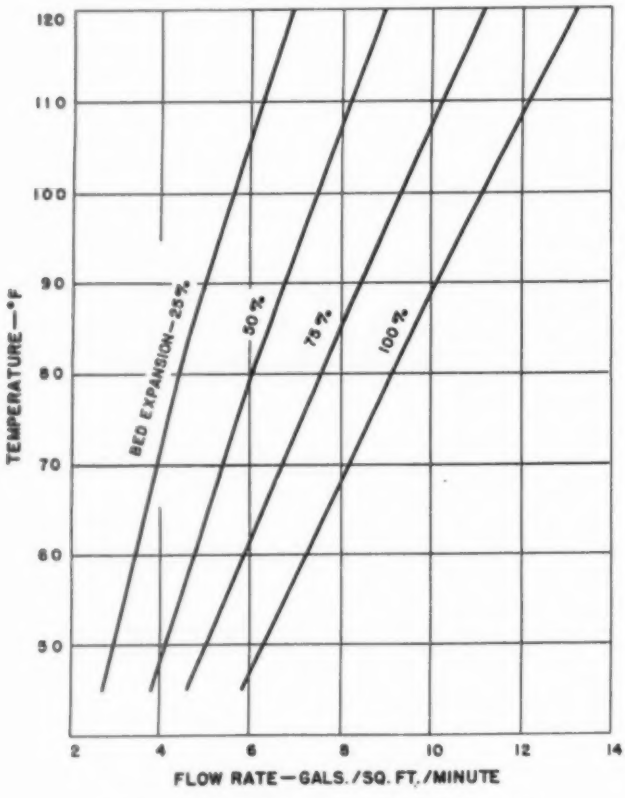


Fig. 1—Backwash Characteristics of a Bed of Cation Exchange Amberlite at Various Washwater Temperatures.

Bumping

When the influent to the ion exchanger contains suspended or dissolved solids that coat the resin particles, and backwashing does not scrub the particles clean, "bumping" can be used to combat a progressive reduction in exchange capacity. This procedure consists of draining the exchange unit completely and thereafter admitting the backwash water so that it will surge violently through the bed, thereby scrubbing the particles vigorously and freeing them of coating. An increase in capacity of about twenty-five per cent between regenerations has been reported by operators in one plant who used this procedure in the middle and at the end of the exhaustion cycle.

With influents to the exchanger containing a high proportion of suspended solids, it is becoming rather common practice to secure attrition of bed particles through use of surface wash units of the type employed in sand or anthracite filter units. In one larger midwestern plant the increase in capacity resulting from the installation of surface wash units in one exchange system has prompted their specification in all other exchange systems.

Control of Microorganisms

Contamination of exchange units by biological growth or microorganisms presents a more difficult problem. The efficiency of Amberlite IR-100 in a southern installation was markedly reduced by organisms in the feedwater. The biological growth formed a "blanket" on the surface of the resin bed, with excessively high head losses resulting. Cracking of this membrane led to channeling, premature break through of ions, and a reduction in the operating cycle. Chlorination of the influent in concentrations of about 2 ppm. effected lower head losses, longer cycles, and less frequent backwashing without altering the chemical or physical properties of the Amberlite exchanger.

In another case, difficulty was encountered with iron-consuming microorganisms, probably introduced in the backwash water. The addition of 5 ppm. chlorine in the backwash water eliminated the objectionably high head losses caused by clogging of the under-drainage system.

Since organic-type exchangers absorb high concentrations of chlorine, it cannot be used to sterilize the ex-

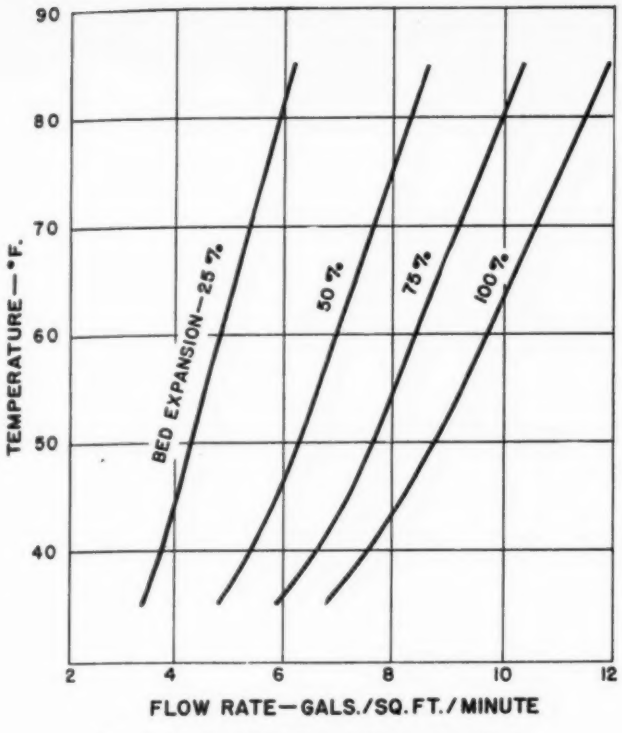


Fig. 2—Backwash Characteristics of a Bed of Exhausted Anion Exchange Amberlite at Various Washwater Temperatures

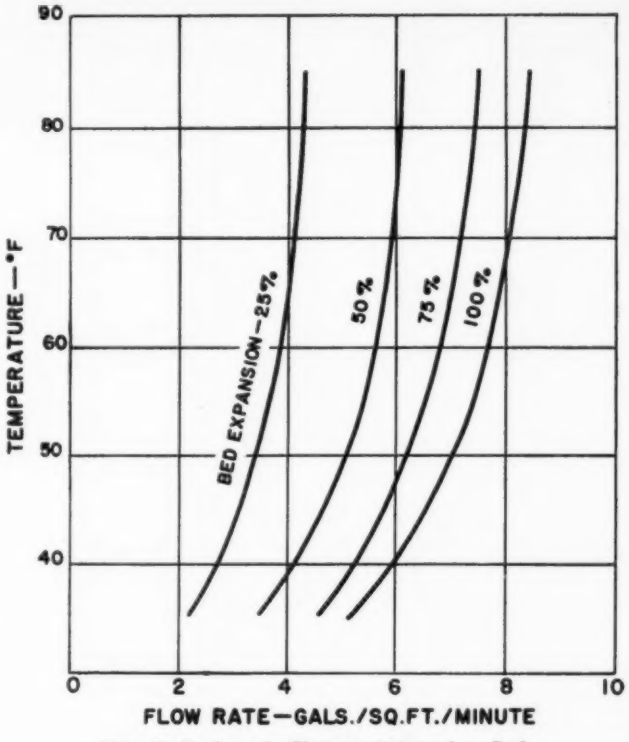


Fig. 3—Backwash Characteristics of a Bed of Regenerated Anion Exchange Amberlite at Various Washwater Temperatures

change beds of the bottling, pharmaceutical, beverage, and food industries. This need, however, has been filled by a sterilizing reagent manufacturer who has developed a compound that gives every indication of killing bacteria without affecting the resin-type cation and anion exchangers.

H. B. Gotaas Heads Calif. U. Civil Engineering

Harold B. Gotaas, Prof. of Sanitary Engineering, Univ. of California, Berkeley, was recently appointed chairman of the Division of Civil Engineering.

Prof. Gotaas joined the Univ. of California faculty in the fall of 1946 after separation from the Army. During the war, Prof. Gotaas held the rank of Colonel and served with the Institute of Inter-American Affairs. Just prior to being separated from the Army, he was made chief engineer and later was president of the Institute of Inter-American Affairs.

During his war service, Col. Gotaas received the Legion of Merit from the United States with a citation for outstanding service in the operation of the Cooperative Health and Sanitation Development Program in the Latin American Republic. In addition to this honor, Col. Gotaas was also awarded the "Cruz de Boyaca" from the government of Colombia.

Advisory Water Pollution Control Board Named by President Truman

President Truman has selected the six non-government members of the 11-man Water Pollution Control Advisory Board, created in accordance with provisions of the Water Pollution Control Act of 1948, PL 845. The men designated by the President are:

Thomas Berrigan, Director & Chief Engr.
Boston Metropolitan District

L. A. Danse, Chairman, Ind. Wastes Comm.
General Motors Corp., Detroit

Stanley Freeburn, Ass't. Dean
Univ. of California School of Agriculture

Michael Klein, Chief Eng'r.
Borough of Manhattan, New York

C. D. Shoemaker, Conservation Director
Nat'l. Wildlife Federation, Washington

N. T. Veatch, Jr., Consulting Engr.
Black & Veatch Engrs., Kansas City, Mo.

The other members, representing Federal departments and agencies named in the law, have been appointed by the heads of their agencies. They are:

James W. Follin, Assistant Administrator
Federal Works Agency

Hugh Arnold, Executive Officer
Chief of Engineers for Civil Works

Milton C. James, Assistant Chief
Fish & Wildlife Service, Dept of the Interior

Ralph Reeves Will
Office of the Secretary of Agriculture

Mark B. Hollis, Assistant Surgeon General and Chief Engr. U.S.P.H.S., has been designated by Surgeon General L. A. Scheele to serve as "Chairman of the Board."

Los Angeles Sells Sewage Bonds for Less Than 2%

A Los Angeles group of security dealers, headed by Bank of America, thought well enough of the $10,000,000 issue of 20-year bonds for sewage disposal improvements to purchase the entire ten million from the city at a price which will cost the city only 1.9499 per cent interest over the 25-year life of the bonds. Most, if not all, of the $10,000,000 will go into the new Hyperion Treatment Plant.

CHEMICALS USED IN WATER & SEWAGE TREATMENT

CHEMICAL NAME AND FORMULA	COMMON OR TRADE NAME	SHIPPING CONTAINERS	AVAILABLE FORMS	WEIGHT lb./cu. ft.	SUITABLE HANDLING MATERIALS	SOLUBILITY Lb./Gal.	COMMERCIAL STRENGTH	CHARACTERISTICS AND USE
ACTIVATED CARBON C	Aqua Nuchar Hydrodarco	Bags	Black Granular Powder	15	Dry—Iron & Steel Wet—Stainless Steel Rubber-Silicon Iron	Insoluble (Suspension Used)		Taste and Odor Removal. Must be Completely Wetted with Hopper Agitation-Dry Feed.
ALUMINUM SULFATE $Al_2(SO_4)_3 \cdot 14H_2O$	Alum Filter Alum Sulfate of Alumina	100-200# Bags 300-400# Bbls. Bulk C/L	Ivory White Pdr. Ivory White Grd. Ivory White Lump	38 to 45 60 to 63 62 to 67	Dry-Steel & Iron Solution-Lead, Rubber Sil. Iron Asphaltum	4.2 at 60°F	15-22% Al_2O_3	Coagulant at pH 5.5-8.0 Sludge Conditioning. Dry Feed Allow 5 Min. Retention. 1% Sol. pH-3.4
AMMONIUM ALUMINUM SULFATE $Al_2(SO_4)_3(NH_4)_2SO_4 \cdot 24H_2O$	Ammonia Alum Crystal Alum	Bags Barrels Bulk	Lumps Nut Pea Powdered	64 to 68 62 65 60	Lead, Duriron, Rubber, Stoneware Silicon Iron	0.3 @ 32 8.3 @ 212	11% Al_2O_3	Coagulant for Pressure Filter Pot Feed-Ammonia for Chloramines. 1% Solution pH-3.5
AMMONIUM SULFATE $(NH_4)_2SO_4$	Sulfate of Ammonia	100# Bags	White to brown crystals		Rubber—Plastics— Ceramics			Combined Residual Chlorination—Cakes in dry feed—Add $CaSO_4$ for free flow.
ANHYDROUS AMMONIA NH_3	Ammonia	50# 100# Cylinders 150#	Colorless Gas		Iron, Steel, Glass, Nickel and Monel	3.9 @ 32 3.1 @ 60 1.8 @ 125	99-100% NH_3	Formation of Chloramines with Chlorine for Water and Main Sterilization.
AQUA AMMONIA NH_4OH	Ammonia Water Ammonium Hydroxide Ammonium Hydrate	Carboys 750# Drums 8000 Gal. T/C's	Water White Lqd.		Iron, Steel, Glass, Nickel and Monel	Completely	26°Be-29.4% NH_4	Formation of Chloramines with Chlorine for Water and Main Sterilization.
BENTONITE $H_2O(Al_2O_3 \cdot Fe_2O_3$ $3MgO)4SiO_2 \cdot nH_2O$	Colloidal Clay Wilkinite Volclay	100# Bags	Powder Pellets Mixed Sizes	60	Iron and Steel	Insoluble (Colloidal Sol Used)		Water and Sewage Coagulant Weighting Agent.
CALCIUM HYDROXIDE $Ca(OH)_2$	Hydrated Lime Slaked Lime	50# Bags 100# Barrels Bulk C/L	Pulverized White Powder	40-70 26-48	Rubber, Iron, Steel Asphaltum, Cement	.014 @ 68 .012 @ 90	85-99% $Ca(CH)_2$ 63-73% CaO	Hopper Agitation Required for Dry Feed of Light Forms.
CALCIUM OXIDE CaO	Quicklime Burnt Lime Chemical Lime Unslaked Lime	50# Bags 100# Barrels Bulk C/L	White Lumps White Pebbles Ground	50-65 60-65 50-70	Rubber, Iron, Steel Asphaltum, Cement	Slakes to Form Hydrated Lime	75-99% CaO	pH Control-pH Saturated Sol. 12.4-Detention, Temperature. Amount of Water Critical for Efficient Slaking.
CALCIUM HYPOCHLORITE $Ca(OCl)_2 \cdot 4H_2O$	"H.T.H." Perchloron Pittchlor	5# Cans, 100, 300 800# Drums	White Granules and Powder	52.5	Rubber, Wood, Glass Stoneware	1-3% Avail. Cl_2 Solu- tion Used	70% Avail. Cl_2	Bactericide, Disinfectant, Slime Control. Solution Feed.
CHLORINATED LIME $CaO \cdot 2CaOCl_2 \cdot 3H_2O$	Chloride of Lime Bleaching Powder	100, 300 & 800# Drums	White Powder	48	Rubber, Wood, Stoneware & Glass		25-37% Avail. Cl_2	Germicide and Disinfectant Deteriorates-Solution Feed.
CHLORINE Cl_2	Chlorine Gas Liquid Chlorine	100-150-200# Cylinders, 16 & 30T T/C's	Green Yellow Gas or Lt. Orange Lqd.		Dry-Steel, Copper & Iron, Wet-Silver, Glass Lead & Hard Rubber	.07 @ 60 .04 @ 100	99.8% Cl_2	Bactericide, Disinfectant, Slime Control. Gas or Liquid Feed.
CHLORINE DIOXIDE ClO_2	Chlorine Dioxide	Unstable— Must be generated as used.	Yellow-red gas		Plastics, soft Rubber—Avoid Hard Rubber	0.024 @ 30mm.	263% Available Cl_2	Control of Tastes and Odors due to Phenols and Algae. Bactericide.
COPPER SULFATE $CuSO_4 \cdot 5H_2O$	Blue Vitriol Blue Stone	100# Bags 450# Barrels Drums	Crystals Lump Powdered	75 to 90 73 to 80 60 to 64	Stainless Steel- Asphaltum-Silicon Iron	1.6 @ 32 2.2 @ 68 2.6 @ 86	99% $CuSO_4$	Algae Growth Prevention in Reservoirs to Prevent Odors and Tastes.
DI-SODIUM PHOSPHATE $Na_2HPO_4 \cdot 12H_2O$	DSP Secondary Sod. Phos. Dibasic Sod. Phos.	200# Bags 325# Barrels 125# Kegs	Crystals	60-64	Cast Iron & Steel	0.4 @ 32 6.4 @ 86	19-19.5% P_2O_5	Boiler Water Conditioning. Ca & Mg Precipitation. pH of 1% Sol. 9.1. Anhydrous Also
FERRIC CHLORIDE $FeCl_3$ 35-45% Solution $FeCl_3 \cdot 6H_2O$ $FeCl_3$	Ferrichlor Chloride of Iron Crystal Ferric Chloride Anhydrous Ferric Chloride	5 & 13 Gal. Carboys Trucks, T/C's 300# Barrels 500# Casks, 100# 300# & 400# Kegs	Dark Brown Syrupy Liquid Yellow Brown Lumps Green Black Pdr.		Rubber, Glass, Stoneware, Synthetic Resins Rubber, Glass, Stoneware Synthetic Resins as above	Completely 5.0 @ 98 4.0 @ 86	37-47% $FeCl_3$ 12-17% Fe 59-61% $FeCl_3$ 20-21% Fe 98% $FeCl_3$ 34% Fe	Water and Sewage Coagulant Sewage Sludge Conditioner Hygroscopic—Lumps and Powder—Store in Tight Containers—No Dry Feed. Optimum pH 4.0-11.0.
FERRIC SULFATE $Fe_2(SO_4)_3 \cdot 9H_2O$	Ferrifloc- Ferrisul	100-175# Bags 400-425# Drums	Red Brown Pdr. or Granules	70-72	18-8 Stainless Steel, Rubber, Lead, Ceramics Plastics	Soluble 2-3-4 Parts Cold Water	90-94% $Fe_2(SO_4)_3$ 25-26% Fe	Coagulant @ pH 3.5-11.0 Mildly Hygroscopic—Dissolving Pot Agitation Required—Dry Feed.
FERROUS SULFATE $FeSO_4 \cdot 7H_2O$	Green Vitriol Copperas	Barrels	Green Crystals, Granules & Lumps	63-66	Concrete, Tin, Lead Wood, Asphaltum		55% $FeSO_4$ 20% Fe	Water and Sewage Coagulant Hygroscopic—Caking in Storage

FERROUS SULFATE $FeSO_4 \cdot 7H_2C$	Green Vitriol Copperas	Barrels	Green Crystals, Granules & Lumps	63-66	Concrete, Tin, Lead Wood, Asphaltum		55% $FeSO_4$ 20% Fe	Water and Sewage Coagulant Hygroscopic-Cakes in Storage Optimum pH 8.5-11.0.
OZONE O_3		Generated at site	Colorless gas		Glass—Aluminum—Ceramics	Max. 1% Avl. Mixture Used		Taste and Odor Control—Bactericide—Oxidizing Agent.
POTASSIUM ALUMINUM SULFATE $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$	Potash Alum	Bags, Barrels Bulk C/L	Lumps Ground Powdered	62-67 60-65 60	Lead, Lead-Lined Rubber, Stoneware	0.5 @ 32 1.0 @ 68 1.4 @ 86	10-11% Al_2O_2	Coagulant—Pot Type Feed. Low Even Solubility. pH of 1% Solution 3.5
SODIUM ALUMINATE $Na_2O.Al_2O_3$	Soda Alum	100-150# Bags 250-325-440# Drums Solution Also	White to Greenish Yellow Crystals Liquid 27° Be′	50-60	Iron, Steel & Rubber Plastics	3.0 @ 68 3.3 @ 86	55% Al_2O_3. 35% Na_2O +5% Excess NaOH (Sol.) 32% $Al_2O_3 \cdot Na_2O$ +10% NaOH (Liq.).	Water Coagulant @ pH 6.0-8.5. Hopper Agitation Required for Dry Feed
SODIUM BISULFITE $Na_2S_2O_5$	Sodium Meta-Bisulfite	Drums	Powder	74-85	Lead, Rubber, Glass Ceramics, Chrome Nickel	4.5 @ 68 6.8 @ 212	93% $Na_2S_2O_5$ 62% SO_2	Antichlor—pH of 1% Solution 4.6
SODIUM CARBONATE Na_2CO_3	Soda Ash 58%	Bags Barrels Bulk C/L	Extra Light Light Dense	23 35 65	Iron, Steel & Rubber	1.5 @ 68 2.3 @ 86	58% Na_2O 99.4% Na_2CO_3	pH Control—pH of 1% Solution 11.2—Hopper Agitation for Dry Feed of Lt. & Ex. Lt.
SODIUM CHLORIDE NaCl	Common Salt Salt	Bags Barrels Bulk C/L	Rock Fine	50-60 58-70		2.9 @ 32 3.0 @ 68 3.0 @ 86	98% NaCl	Regeneration of Zeolites.
SODIUM CHLORITE $NaClO_2$	Technical Sodium Chlorite	100# Drums	Light Orange Powder-Flakes		Metals—Avoid Cellulose materials.		82% $NaClO_2$ 130% Avail. Cl_2	Powerful Oxidizing Agent. Generates ClO_2 at pH 3.0. Store in metal containers only.
SODIUM FLUORIDE NaF	Fluoride	Barrels Kegs	Nile Blue or White Powder Light Dense	50 50 75	Iron, Steel & Lead 316 St. St.	.35 @ Most Temps.	90-95% NaF	Water Treatment to Prevent Dental Caries. pH of 4% Solution 6.6.
SODIUM HEXA-META PHOSPHATE $(NaPO_3)_6$	"Calgon"	100# Bags	Glass Flake Powdered	47	Stainless Steel, Hard Rubber, Plastics	1 to 2 Common 4.2 Pos'bl	(Unadjust.) 66% P_2O_5	"Red Water" and Precipitation Prevention. .25% Solution Various Forms Approx. pH 6.0—8.3
SODIUM HYDROXIDE NaOH	Caustic Soda Soda Lye	100-200-400 & 700# Drums, Trucks, TC's	White Flakes 76% Na_2O Solid 50% Na_2O Liquid		Cast Iron, Steel & Rubber	2.4 @ 32 4.4 @ 68 4.8 @ 104	FL&S98.9% NaOH 74-76-Na_2O	pH Adjustment. Hygroscopic solid. Solution Feed Only. 1% Solution pH 12.9.
SODIUM HYPOCHLORITE NaOCL	Various	5 & 13 gal. carboys Tank Trucks 1300-1800-2000 gal.	Lt. Yellow Liquid	9.8-10# per gal.	Rubber-Plastic Glass-Ceramic	Solution	12-15% Avail. Cl_2 10.7-13.3% by Weight	Bactericide—Slime Control—Disinfectant—Solution Feed.
SODIUM SILICATE $Na_2O \cdot SiO_2$	Water Glass	Drums Trucks T.C's	Opaque Viscous Liquid		Cast Iron, Steel & Rubber	Completely	38-42°Be. (Activated Brands Also)	Coagulant Assistant, Corrosion Control. Variable Ratio Na_2OSiO_2 1%Sol. pH12.3
SODIUM SULFITE Na_2SO_3	Sulfite	Bags Barrels	Powder	80-91	Cast Iron & Steel	1.2@ 32 2.3 @ 132	93-99% Na_2SO_3	Oxygen Removal in Boiler Water Treating. 1% Sol. pH-9.8.
SODIUM THIOSULPHATE $Na_2S_2O_3 \cdot 5H_2O$	Sodium Hyposulfite Hypo	Bags Barrels Drums Kegs	Standard Crystals Rice Fine Granular	64-65 65 70 61	Cast Iron, Stoneware Low Carbon Steels	6.2 @ 32 @ 140	98-99%	Antichlor, water neutral.
SULFUR DIOXIDE SO_2	Sulfur Dioxide	100-150 & 200# Cylinders	Gas		Dry—Steel		100% SO_2	Antichlor and Cleaning Filter Beds.
SULFURIC ACID H_2SO_4	Oil of Vitriol Vitriol	Bottles, Carboys, Drums, Trucks, T/C's	66°Be Solution 60°Be Solution		Conc.—Steel & Iron Dilute—Lead, Porcelain Glass, Rubber	Complete	66°-93.2% H_2SO_4 60°-77.7%	pH Control 0.5% Solution Approximate pH—1.2.
TETRA SODIUM PYRO-PHOSPHATE $Na_4P_2O_7 \cdot 10H_2O$	TSPP Alkaline Sod. Phrophosphate	200# Bags 300# Barrels 125# Kegs	White Powder	68	Cast Iron & Steel	0.6 @ 80 3.3 @ 212	53% P_2O_5	Water Stabilization. pH of 1% Solution 10.8.
TRI-SODIUM PHOSPHATE $Na_3PO_4 \cdot 12\ H_2O$	TSP Tertiary Sod. Phos. Normal Sod. Phos.	200# Bags 325# Barrels 125# Kegs	Coarse Crystals Med. " Std. "	56 58 61	Cast Iron & Steel	0.1 @ 32 13.0 @ 158	19% P_2O_5	Boiler Water Conditioning Cleaning Compound. pH of 1% Solution 11.9. Anhyd. Also

Developed by Henry F. Munroe of Proportioneers Inc., Providence, R.I.

ALGAE CONTROL

Two Methods Found Effective for Algae Control in Swimming Pool Operation

by
F. J. McINTYRE*

WHEN copper sulfate is added to water containing hardness, a reaction takes place between the copper and the minerals in the water. The formation of copper carbonate is noticed as it is very insoluble and will separate from the water as a precipitate that settles on the pool bottom. This copper precipitate has little or no effect on algae. Copper must be in solution to be toxic to algae.

Cupric-Chloramine Treatment

This leads to the cupric-chloramine treatment, which is merely a combination of copper chlorine and ammonia. The formation of this compound is accomplished by first dissolving the desired amount of copper sulfate in the least quantity of water (1 lb. per gallon) and adding, slowly, ammonium hydroxide, with constant stirring until all the copper ions are thrown out of solution. This is noticed by a milky precipitate. Then, continue adding ammonia until this milky precipitate is redissolved. This change is noted by the milky solution turning to an indigo-blue clear solution, which must remain clear and blue on stirring. When the solution stays clear blue, enough ammonia has been added.

This solution is then added thru a hypochlorinator ahead of the chlorinator, with the chlorinator turned to a rather high dosage (5 ppm. if possible). If a hypochlorinator is not available the copper solution may be added to the water by feeding it into the water just over the pool inlets. The chlorine content of the water must be watched with this treatment, as it tends to build up beyond control. To eliminate this, the chlorine should be turned off as soon as the residual starts to build up very high (above testing standards used). The chlorine is allowed to be shut off until the residual starts to drop. When down to between 0.7 and 1.0 ppm. the chlorinator is again started and if the residual cannot be held with the chlorinator increased in dosage then repeat the operation. This should only be repeated twice per week at the most.

The above procedure keeps the treatment fluctuating as to chlorine and copper contents and prevents the algae and bacteria from building up a resistance to the treatment. If the chlorine or copper is kept at a constant concentration or residual the bacteria and algae will get accustomed to them and continue to grow.

The secret of good pool operation appears to be the fluctuation of the concentration of treatment to prevent the organisms from building up a resistance to the treatment.

Quaterinary Ammonia Treatment

Another treatment for the prevention of algae is the use of some of the quaterinary ammonia compounds. I have used two of these with good results. One used is "Q.A.S.", which is made by the Mathieson Chemical Co. I used this in a 10% solution in the ratio of 1 gal. "Q.A.S." to 40,000 gal. pool water, once per week. With this dilution it is possible to entirely eliminate the formation of algae in pool waters. In greater dilutions (twice that) it may work in some cases. Another was para di-isobutyl phenoxy ethoxy ethyl dimethyl benzyl ammonium chloride monohydrate 10% solution and in the same dilution.

The "quats" eliminate the turbidity produced with copper treatment and I have not had any interference with the chlorine residuals or in testing for chlorine. Not all "quats" are usable for this purpose I am told.

*Director, Columbus Water & Chemical Testing Laboratory, Columbus, Ohio.

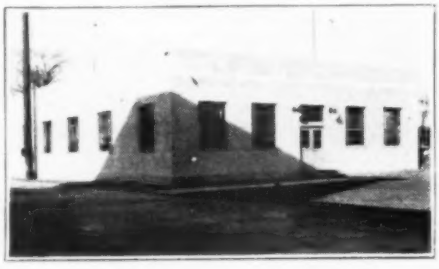
PHILADELPHIA BEGINS OZONATION OF WATER

On March 14, 1949, the City of Philadelphia began operation of the world's largest ozone generating plant for water purification at the Belmont Filtration Plant in West Philadelphia.

The construction and installation of this plant followed a two-year test period performed by representatives of the Welsbach Corp., manufacturers of the equipment, and the Philadelphia city water engineers.

Shown in the accompanying photograph is the building housing the ozonator. A picture of the ozonator itself was published in the January issue of *Water & Sewage Works* and its construction reviewed in the Annual Review of Water Development for 1948.

The ozone plant was constructed at a cost of $600,000 and is currently treating approximately 36 mgd., but



it is anticipated that the ultimate capacity will see 70 mgd.

Ozone is added to Philadelphia water for the sole purpose of removing taste and odor compounds.

Rhode Island's Blackstone Valley to Abate Pollution

The Blackstone Valley Sewer District Commission of Rhode Island has awarded its first construction contract to abate pollution of the Blackstone Valley District, which includes the cities of Central Falls and Pawtucket and the towns of East Providence, Cumberland and Lincoln. This district is located in the northeast corner of the state, the farthest point being located only 12 miles from the capitol city of Providence. Twenty-four per cent of the State's industry is located in this area which covers only seven per cent of the State's land area.

The first contact called for the construction of 5,700 ft. of 7 ft. 6 in. sewer and 675 ft. of 24 in. sewer plus appurtenant work.

THE FUTURE OF HOME GARBAGE GRINDERS*

by

MARK B. OWEN

Consulting Engineer
INDIANAPOLIS, IND.

IT HAS been said that the farther back one can see the farther ahead one may look. Therefore, a resume of the past of garbage collection and disposal may be helpful in making a forecast of the future of this subject. One cannot well examine the history of garbage disposal methods without a simultaneous look at the related methods in the rubbish category.

A Look Backward

The collection and disposal of community waste materials has been aptly called the "No. 1 Municipal Headache." Moreover this problem is not new, nor is it unique to present day cities. For two thousand years garbage disposal has occupied some part of the time and thinking of officials of every community, be it a cross-roads hamlet or large metropolitan area. For instance, among the many antiquities of ancient Rome is an inscription on a pillar, "Take your refuse further, or you'll be fined." Our present-day sign doesn't suggest that you carry your refuse further; it simply reads, "No Dumping—Period."

Consider the economical disposal method called sanitary land fills. This is not as original as one might think because on the Island of Crete has been found and restored an ancient sanitary fill dating back to 1900 B.C. This is a stone-lined pit into which the public refuse was dumped and covered with earth, both in alternate layers. That may well have been our first controlled sanitary land fill.

The "Harlem" method of garbage disposal is fascinating, but not new. New York City Harlemites live in tenement buildings, four, five or more stories high, built solidly along the street and coming within a few feet of the rear of the buildings on the next street to the rear. Consequently there is no alley but only a narrow area way for a rear yard. In recent years, commercial, flat-roof one-story buildings called "taxpayers" have been built on Park Avenue and abutting the tenements at the back. Refuse was simply tossed out the nearest window and allowed to fall where it may. Huge piles of refuse accumulated in the area ways before someone finally removed it. The one-story "taxpayers" with their flat roofs and encircling parapet walls were targets surpassing even the silk-hatted man in snowball time. Naturally, these roofs had to be cleared periodically. The first few days after each cleaning were really the most interesting ones because then one could almost calculate with precision—due to the burst pattern of the missile—the window from which a nice juicy bag of garbage emanated by the angle of repose.

The "Harlem" method of disposal was in use in England back in the days of the Tudors and Stuarts. English history reveals why luxury and squalor produced the terrible plagues of those times. The peasants lived in wigwam hovels made of reeds and sticks plastered over with mud: the "well-to-do" covered their earthen floors with rushes which became saturated with food scraps and putrified under a new layer of rushes scattered over it. In time "Petremen" came to dig salt petre out of the floors. While salt petre is a natural salt found in various parts of the world it may also result from the putrefaction of animal and vegetable matter. The peasants lived on narrow dirty streets into which all of the refuse from the houses was thrown. The stench was so bad "it was necessary to light bonfires at night in the streets." The word "bon" in French meaning good—hence, good fires, "which had great virtue to purge the infection of the air."

Along the East coast some sewage plants dispose of sludge by barging to sea. That is not original either because refuse was barged to sea in England in the 18th Century. It had to be stopped there because, as one writer said, "the fisherman's nets became too full of old hats and shoes."

As recently as 1890 a great many towns in England disposed of refuse by dumping or piling in heaps. This practice was referred to as putrefaction. One writer of that day said, "It remains for this so-called 19th Century to pile up its heaps of putrescible matter and leave them to undergo the only possible change,—putrefaction. Only when all available waste spaces, quaries and pits, have been filled up has sheer necessity driven local authorities to another method of disposal."

One of the earliest attempts to burn refuse in Eingland was made in 1870. In the next twenty years a great variety of inventions developed for destroying refuse. One proposed scheme was a "traveling destructor something like a traction engine to go its rounds at night, and browse as it went along upon the refuse collected from door to door—veritably an awe-inspiring machine."

So much for the past, and probably so much for the thesis that there is nothing new under the sun in garbage disposal because there is something new and unique—the household garbage grinder or disposer. Even so, sewage plant operators may not consider it entirely unique because a casual examination of the materials captured on the screens of sewage plants years ago revealed nearly every item of food waste discharged in household kitchens.

Water transportation is famous for its relative cheapness. What could be less expensive than water carriage of ground garbage by gravity, particularly when it has no appreciable effect on the hydraulics of the carrying system. Logically, one may ask, "Why not utilize the sewer system to transport all of the garbage of the community?" The answer to this question is best provided after an examination of the community's sanitary disposal facilities comprising the sewer system, sewage works, and garbage and rubbish collection and disposal methods. Further, the study must consider the average cost, installed, of garbage disposers, the percentage of dwellings with plumbing systems that will accommodate the disposers, and the size of the garbage problem remaining due to substandard house plumbing. Last—and mentioned last for the sake of emphasis—the first step in an examination of the problem in any community should be taken to define garbage physically and chemically.

What Is Garbage

Garbage comprises the discarded vegetable and animal matter resulting from the preparation and consumption of food in kitchens. It will vary from 70 to 80 percent in moisture, 3 to 5 percent in ash, and 27 to 15 percent in volatiles or combustibles.

One of the least known and consequently generally ignored, but most important characteristic of garbage is the composition of the substance in terms of the basic elements.

Both garbage and sewage solids are produced from the preparation and consumption of food. The latter substance has been subjected to metabolism in the human body, while the former has not. A comparison of the chemical composition of raw garbage and undigested sewage solids, collected in a community is shown in Table I:

TABLE I

Ultimate Analyses

Element	Dry Solids Per Cent by Weight	
	Garbage	Sewage
Carbon	45.2	45.1
Hydrogen	5.6	6.1
Oxygen	31.6	24.4
Nitrogen	2.1	3.3
Sulphur	0.3	1.0
Ash	15.2	20.1
Total	100.0	100.0

On the basis of volatile, or combustible solids only, the above comparison is shown in Table II:

TABLE II

Ultimate Analyses

Element	Combustible Solids Per Cent by Weight	
	Garbage	Sewage
Carbon	53.3	56.5
Hydrogen	6.6	7.6
Oxygen	37.3	30.6
Nitrogen	2.5	4.2
Sulphur	0.3	1.1
Total	100.0	100.0

It is believed the sewage, from which the above solids were taken, was mostly domestic in character. Industrial wastes will materially affect the chemical character of sewage solids.

Two questions logically arise: (1) Why are the two substances, one already digested in the human body, so nearly alike in chemical constituents? The answer is not forthcoming.

(2) In view of the almost identical composition of the two substances—sewage and garbage solids—will the sewage treatment process know which kind of solids are being received. The answer obviously is No.

Quantity of Garbage

The quantity of garbage produced in a community is influenced by the geographical location of the community, the seasons, and

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the habits and economic status of its inhabitants. More garbage is produced in the so-called "silk stocking" districts than in the slums. Moreover it is a "richer" garbage.

In the South where they have longer growing seasons, more green stuffs are consumed than in the North.

Over a period of years the composite habits and wealth of an area will produce a quantity of garbage that is fairly constant in terms of pounds per capita per day. The variation in production between areas is well illustrated by the following indices:

Region	Index
New England	100
Middle Atlantic	127
East North Central	132
East South Central	159
Mountain	100
Pacific	112

It will be noted that the highest production of garbage is in the East South Central states, which is largely due to the longer growing season with a higher consumption of green stuff. The next highest rate is the East North Central region.

In our particular temperature zone we may expect the maximum quantity of garbage to be produced in August and September, and the minimum to occur in February. Of the annual amount, almost 12 percent will be produced in September and little less than 6 percent in February. Another way of stating the variation is the maximum month is 140 percent of the average month, and the minimum is 70 percent.

Unfortunately too many published reports of garbage collection are unusable because the quantities are based on guesses and/or conversions from bushels or cubic yards to pounds.

A rather comprehensive survey covered nearly 6,000 collections in a six-day period, representing over 7,900 families. The quantity of garbage collected averaged 0.55 pound per capita per day. A more recent study was made in a city where new garbage receptacles were furnished to each family of a selected group. The actual number of people contributing garbage during a seven-day period was known, as well as the weights of garbage discarded. The average in this case was 0.52 pound per capita per day. (Actually, the quantity varied from 0.202 lb. per capita per day to 1.50 lb. per capita per day, with an average of 0.691 lb. However, this sampling was made during the peak in August. On the basis of August garbage representing about 11 percent of the annual quantity, the annual average is 0.52 lb. per capita per day.)

In order to illustrate the size and variation of the garbage problem, we may use the above average data for a particular city of 60,000 persons. In this illustration, garbage is conservatively assumed to average 75 per cent moisture, 21.5 per cent combustible matter and 3.5 per cent ash.

In this city then, the wet garbage collected will average 31,200 lb. per day, with a monthly average of 949,000 lb. (Maximum monthly load will be 1,332,400 lb. and minimum monthly load will be 660,500 lb.) The daily dry solids content of this garbage will average 7,800 lb. with a volatile matter content of 6,710 lb. per day. On a per capita basis the dry solids garbage load will be 0.13 lb. per day or 0.11 lb. of volatile matter per capita per day.

We may now compare the quantities of sewage and garbage produced per day in this same community of 60,000 people. In making this comparison one must remember that 100 percent of the population does not contribute either garbage or sewage. Undoubtedly more people contribute garbage than sewage. On the other hand, the influence of industry may tend to minimize the difference. Practically, therefore, we may disregard this disparity.

Quantity of Sewage Solids

Using available sewage data from the same community of 60,000 people, we find the average daily dry sewage solids load to exceed 19,000 pounds, as measured by suspended solids. Consequently, if all of this community's garbage were sent as suspended solids to the sewage plant, it would increase the average suspended solids load therein by approximately 41 per cent. Increasing the quantity of garbage produced per person per day by one pound would increase the suspended solids load at the sewage plant by about 79 per cent.

If we assume that 50 per cent of the suspended solids are removed in the primary settling basins, then the raw sewage solids loading on the sludge digesters would be 9,500 lb. per day in the case of sewage alone, or 13,400 lb. per day in the case of sewage plus garbage (at 0.52 lb. per cap. per day). Their values ignore the small quantity of dissolved solids in the raw sludge.

For more than 50 years incinerator people have used rule-of-thumb factors for "shotgun" estimates of the size of refuse disposal problems. Indeed, a large number of incinerator plants have been designed and constructed on the basis of such estimates. Those factors are—1½ pounds of refuse per person per day, containing 65 per cent by weight of garbage and 35 per cent by weight of rubbish.

Because our standards and habits of living have changed radically in the last 50 years, refuse can no longer, in my opinion, be designated as 65/35 mixture. As a matter of fact, actual samplings made recently by the writer indicate the reverse may be expected. In the writer's opinion the production of garbage will never, in the average community, be as high as one pound per capita per day; but on the contrary will decrease while rubbish will increase. A moment's reflection on the packaging of all items of food in glass and metal, as offered today, illustrates one source of the increasing rubbish quantity with a corresponding decrease in inedible food resulting therefrom.

The foregoing discussion has been based on 100 per cent of the municipal garbage being delivered at the sewage plant via the sewers and discharged therein by household grinders. In our time at least, we shall never see 100 per cent of the dwellings equipped with garbage disposers.

Further, some fundamentals have been set up which we may use in measuring the probable practical effect on sewage treatment works, once we have established the future of household garbage disposers.

Rather than cry "Wolf" and pass thoughtless legislation prohibiting the use of these units, let's be sensible and examine the probable future problems that will arise; based on the sales saturation that may be realized by the manufacturers of such equipment.

Future of Domestic Garbage Disposers

In 1936 at the 42nd Public Works Congress in Toronto, the writer presented a paper entitled, "Grinding as a Process in Garbage Disposal." The use and future possibilities of central garbage grinding stations was discussed, as was the then fairly new idea of household garbage grinders, and some pertinent comments made, primarily for the benefit of sewage treatment plant designers.

In that paper the writer said of householder grinders:

"At the present price of installing this device, only a very small percentage of the homes will be enjoying this convenience. For some time, perhaps, home grinders may not cause any difficulty, if at all, in either the matter of house plumbing, or effect at the sewage works. Present installations will undoubtedly be confined to the higher priced houses where plumbing systems should be entirely adequate for the purpose, if not actually designed for it. The garbage disposer may, however, enjoy a history like that of electric refrigerators. In that case we shall see a great majority of home owners acquiring and using them. We may even witness their universal use in apartment houses before that time. It is the belief of the writer that garbage grinding in the home is with us to stay, and that its use will become more common. Sewage plant operators are going to have this additional load to handle some day and should make plans now to provide for it."

As of today there is no change in the writer's opinion regarding this subject. But for World War II we probably would see wider use of household garbage disposers.

The sale and use of garbage disposers may well have a history paralleling the electric refrigerator. Indeed, it may well follow the pattern of all household appliances, including moreover, the automobile. (See accompanying figure.)

In the appliance industry we have available the experience and history of how business develops from the *Introductory* period, through the *Acceptance* to the *Demand* stage. A realistic approach to the future of disposers can, therefore, be made using the factual experience at hand.

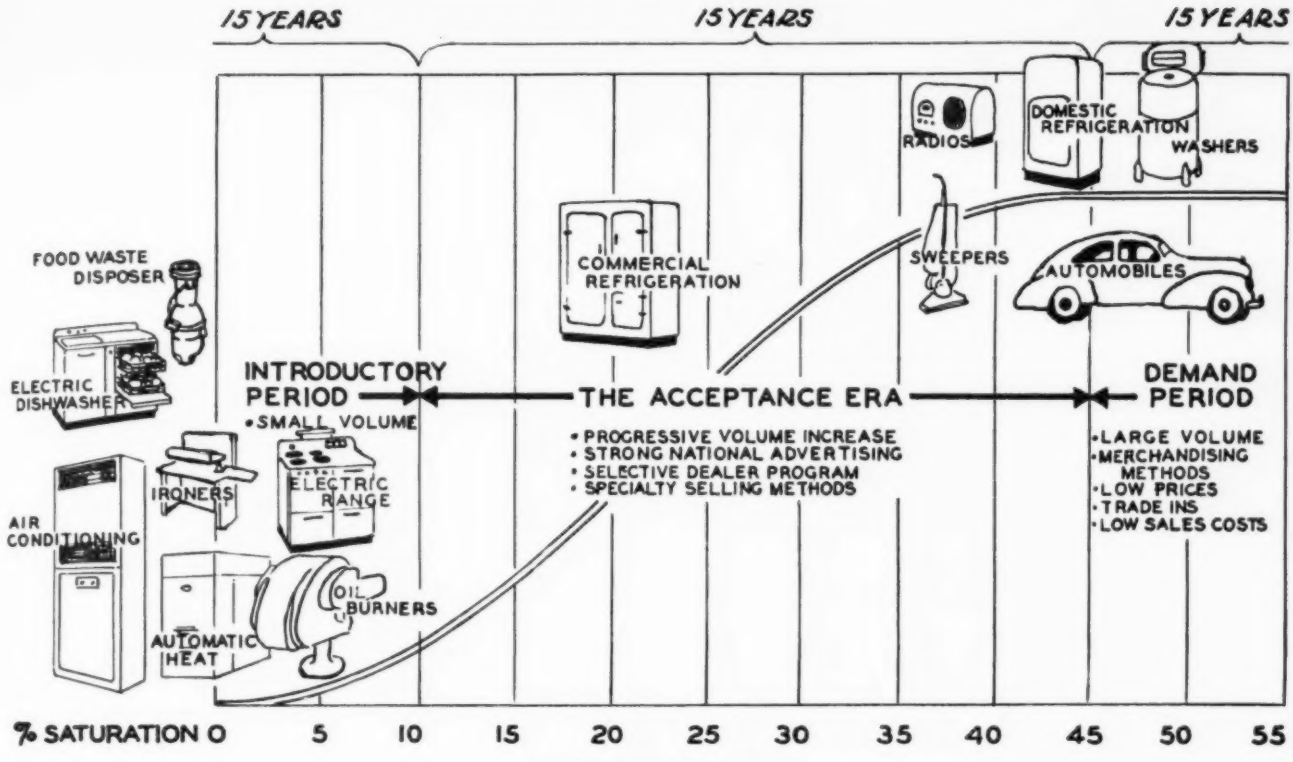
Appliance manufacturers have learned that it takes about fifteen years—the Introductory period—to obtain Acceptance of an appliance. During the Introductory period sales of an item may represent a saturation in the market of ten per cent. During this period many manufacturers enter the field. While prices of the product are high and distribution below par, the quality of the product improves. Finally, the time arrives when the appliance has a million users. From then on the appliance is said to be in the Acceptance period.

The ensuing fifteen years covers an Acceptance period during which time the sales reach 45 to 50 per cent of saturation. In the following Demand era sales volume is high, prices lower and distribution widened.

Washing machines, automobiles, and refrigerators are now in the Demand period. Radios and vacuum cleaners are at the end of the Acceptance era. Still in the Introductory stage are electric ranges, oil burners, dishwashers, ironers, air conditioning, television and household garbage grinders.

You may recall that electric refrigerators were at one time considered a luxury item for the rich. About 250,000 units were sold annually at that time. Now the sales volume is almost 4,000,000 per year. The good experience people have with electric appliances is bound to make the newer items easier to market. Yet, in 1940 the census data for Indianapolis showed that only 54 per cent of the dwellings had mechanical refrigeration, while 6,311 dwellings had no refrigeration of any kind.

More pertinent to our subject is the census data on plumbing systems in Indianapolis as of 1940. Out of 104,928 dwellings canvassed, 11,586 or 11 per cent, did not have running water. Another 8,410 dwellings had running water but no toilets. In other words, abopt 35,000 people could not use garbage disposers. How many more



Development of Industry

(How a business develops from the Introductory Period through the Acceptance Era to the Demand Stage)

dwellings there were with plumbing systems inadequate for garbage is not known. The census report, however, does show that about 18,500 places, or almost 18 per cent, required major plumbing repairs. My guess is that about 25 per cent of the dwellings in the average community have plumbing systems that would not accommodate garbage disposers.

Garbage disposers are now about fifteen years old, and in spite of the last war will soon emerge into the second, or Acceptance period. If this appliance follows the trend just described, we can expect that by 1965, about 45 per cent of the dwellings will be so equipped.

If this forecast of the future use of disposers is reasonable, we can re-examine the theoretical sewage load earlier discussed and make some practical adjustments.

Again using a population of 60,000 people, producing a garbage at a rate of 0.52 pound per capita per day with 50 per cent using household disposers, the average solids load per day received at the sewage plant is shown in Table III.

In artillery parlance, we have now bracketed our target. The ultimate load appears to be 100 per cent of the people producing about 0.5 lb. of garbage per person per day and contributing all of the waste to the sewers. That would increase the suspended solids load at the treatment plant by about 41 per cent. The probable increase in load appears to be about 20 per cent, or about a 20 per cent increase in digested sludge.

Types of Household Disposers

At the present time there are seventeen organizations offering household garbage disposers. A partial list comprising the better known units is given alphabetically.

Disposall by General Electric
Disposall by Hotpoint, Inc.
Eureka Dispos-o-matic by Eureka Williams Co.
Homeurt by Sears-Hockley Machine Co.
In-Sink-Erator by In-Sink-Erator Mfg. Co.
Kaiser by Kaiser Fleetwing Sales Corp.
Mullinaider by Mullins Mfg. Corp.
National by National Rubber Machine Co.
Sanway by Thos. W. Berger, Inc.
Waste-Away by Westinghouse Elec. Corp.
Waste-King by Given Mfg. Co.
Wastemaster by Lockley Machine Co.
Wonder-Aid by Wonder Aid Prod., Inc.

Generally speaking, all of the disposers utilize one of two grinding principles—the modified swing-hammer or the rotating table that throws the waste against stationery cutters. (Editor's Note: At this point Mr. Owen's paper discussed the design features of the various disposers. This material is not reproduced since it is not pertinent to the subject of garbage treatment with sewage.)

TABLE III

Suspended Solids, Total		19,000 lb.
Dry Garbage Solids		3,900 lb.
Total Suspended Solids		22,900 lb.
Per cent dry garbage solids of total		17.0
Per cent increase of dry solids due to garbage		20.5
Volatile Solids		
Sewage	13,300 lb.	
Garbage	3,120 lb.	
Total	16,420 lb.	
Digested Sludge (50% of volatiles digested)		14,690 lb.
Digested Sludge—Sewage only		12,350 lb.
Per cent increase in dry digested sludge due to garbage, per cent		19.0

The Case for the Disposer

Any one could itemize the many ills identified with the ox-cart age garbage can. It seems trite to call attention to the obnoxious odors, the flies, maggots, distasteful cleaning operation, garbage strewn by roving dogs, battered cans and covers caused by careless collectors, trips through the snow at night or early morning to get the can to the curb for the collector, frozen contents that won't dislodge, the lost lid, etc. etc.

Experience has established that the disposer requires less than 2 gal. of water per cap. per day. The calculations herein indicate that the suspended solids load will not increase more than 20 per cent in the next 15 years and that by small annual increments. Disposers have been improved mechanically so that operating troubles should be negligible.

The cost of operation per day is about equal to the cost of running a one-third horsepower motor, one minute per person per day.

The increasing use of new detergents and wetting agents by the housewife, such as Vel, Calgonite, Swerl, Fab, and many others, aids in emulsification of fats and oils. Adherence of those substances to plumbing and sewer surfaces is practically eliminated. As a matter of fact, the above practice coupled with the scouring action of the garbage slurry gives evidence that drains so used are cleaner than when they did not convey ground garbage.

In the Minneapolis-St. Paul Sanitary District it has been calculated that if every family in the district installed a garbage disposer, the additional cost, capital and operating, would be the equivalent of 55c per person per year, for the district's particular type of plant—chemical precipitation. On a comparable basis, the total cost of collection and disposal by any other method in general use today would be at least 75c per person per year.

A more comprehensive discussion of this subject is beyond the scope of this paper. Those who are responsible for the operation and maintenance of sewage treatment works will appreciate that only the major, but probably the most important points have been covered. It should also be realized that contrary to some published information the household garbage disposer is no ogre about to destroy sewage treatment processes and plants.

SEWER STABILIZATION VIA SUSPENSION

by

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IN 1928 the Department of Water and Sewerage of the City of Shreveport, Louisiana, installed a reinforced concrete pipe sanitary sewer outfall, 24 inches in diameter and 26 feet deep, in the lowland of the Red River bottom. The soil in which this sewer was laid was built up by Red River deposits of many years standing, consisting of fine silt clay and other matter carried off by a rapid turbid river. Many strata of soils are found in the make-up of this river deposit, but the condition that gave us the most trouble was a fluid sandy silt, similar in many ways to pottery clay with just enough water to cause it to run freely.

This material is not quicksand but a liquid oozing matter that trench de-watering could not consolidate, but as long as there was enough water, diaphragm pumping would handle it. As the liquid was displaced from the trench, the fluid-like matter from the bottom would rise or work its way up from the bottom and side wall until the sheeting, as the sketch shows, was driven to a point 7.0 ft. below the grade of the pipe. This method of pumping and driving sheeting made it possible to bring the excavated material to about a foot below the pipe grade, allowing us to install the pipe in the manner which the accompanying sketch and photographs reveal. The cast-iron pipe was swung on cables supported from 8 in. x 8 in. beams placed across the ditch with end bearing on the 3 in. x 10 in. x 20 ft.

The Completed Trench, Sheathed and Ready for Suspending the Pipe.
(See Detail Sketch)

timber, securely fastened on the tops of the 2½ in. x 10 in. x 16 ft. sheeting, previously driven to place. The sheeting was supported by 8 in. x 8 in. x 20 ft. rangers, braced across the ditch with 8 in. x 8 in. braces spaced about 5 to 6 ft. apart. This formed a suspended foundation for the pipe.

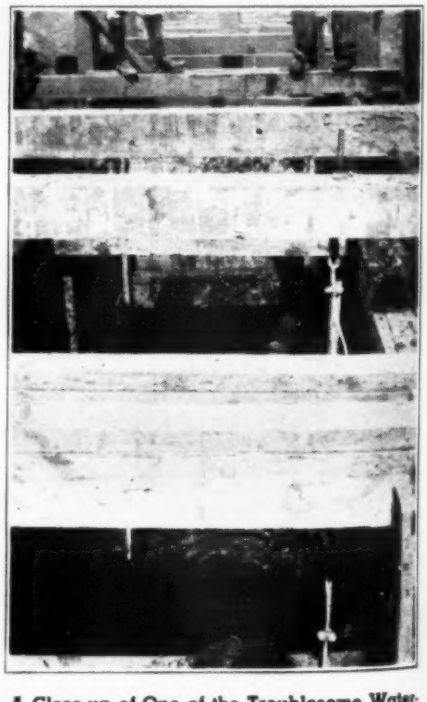
The space of about 12 in. below the pipe is filled with crushed stone to form an additional foundation for the pipe after it becomes set. Seeping of water running through the voids around the rock finally closed them with sand. No timber was placed under the pipe as was done in the original installation of this sewer.

Adding to the stability of the foundation, after the pipe has been installed and fill-in is completed under the pipe, is the wedge shaped area. However, we depended entirely on the suspension as the true foundation.

The upper section of the sheeting can be removed, if desired, before backfilling the trench. It has no effect on the foundation.

The original foundation, as indicated in the sketch, consisted of fabricating a timber bottom by laying 2 in. x 8 in. boards the width of ditch crosswise and on top of these 2 in. x 8 in. x 16 ft. boards placed longitudinally are spiked to the lower layer. Then two more layers were added to make four full layers on top of which was placed the pipe shimmed up to proper grade. Any voids existing were filled with crushed stone and sand, allowing the seep water to rise to help fill the voids with solid matter. This foundation held up for seven years and would have held up longer had not the joints begun to leak when under the pressure of a full pipe. Thereafter, flowing less than full, infiltration into the pipe carried with it the fine silt and sand until such time as a large cavity was formed. In fact, at times the sewer acts as a suction

Close-up of Suspended 24-in. Universal Pipe Ready for Bolting-up.



A Close-up of One of the Troublesome Water-Boils Beneath the Suspended Line.

line which draws the material into the pipe through leaky joints, and it is carried away to the station or river. The daily repetition of such action soon causes a cavity to develop about the joint or opening and finally this cavity appears at the surface of the ground, 26 ft. above the faulty joints.

The displacement of the material around the joints soon weakens the line. Settlement of the pipe further aggravates the condition and hastens the ultimate collapse.

In not one instance, however, did we find a crushed or broken joint of pipe, and we replaced over 2300 feet. Every piece of pipe had been inspected and certified to in 1928 by a chemical engineer in our employ before laying.

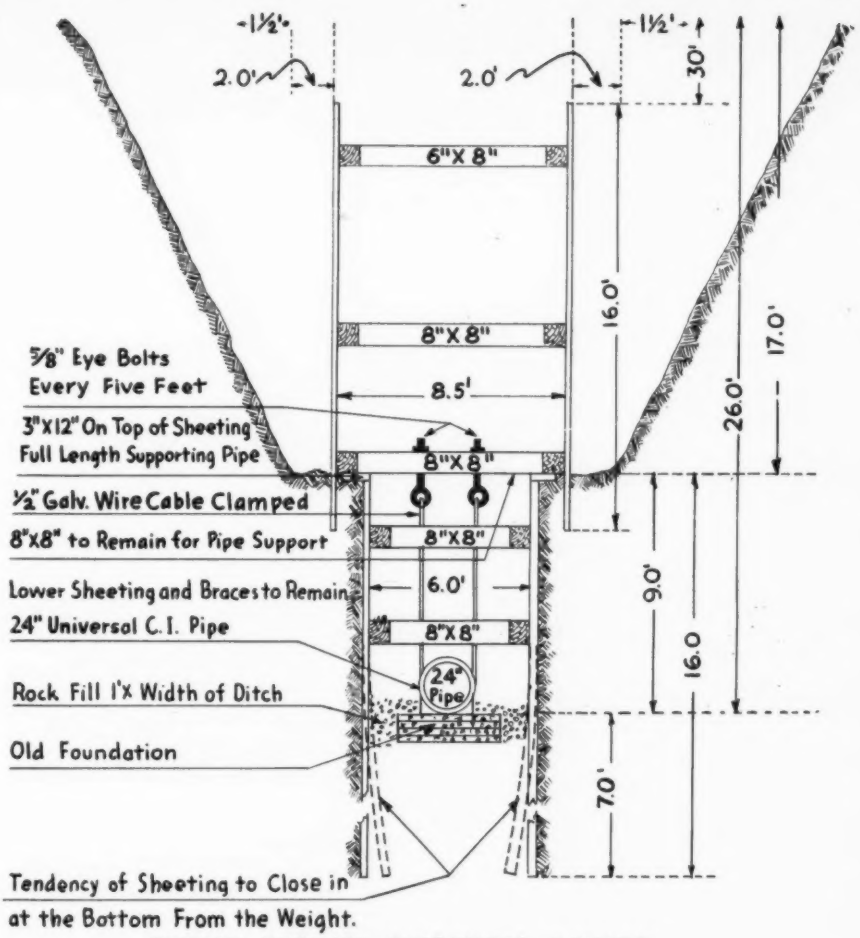
The method of stabilization herein described has proved satisfactory, as we have not had a joint or pipe failure since its adoption more than 12 years ago.

Bolted Joint Cast Iron Pipe Used

After using other types of pipe, we found the 6 ft. length cast iron Universal Joint pipe to be the most adaptable, because of the easy to handle short lengths and semi-flexible joints, with only four bolts to make up the joint. This pipe had to be laid in running water as there was no way to by-pass it. The sewer was never taken out of service during the repairs. Such circumstances makes lead, compound, or cement joints hard to make, costly and altogether impractical.

Cost Comparisons

In analyzing the cost items, we used the ordinary drag line machine with a five-eighths yard bucket; also pile driver and hammer equipment for driving the piling and sheeting. We also used the machine boom to handle the timbers and pipe, which made it an 80 per cent machine job. Concerning the backfilling, this was less by hand than by machine and involved the use of a hydraulic method. Employing a pump to furnish water pressure, source of the water being the sewage flow, we used a filter-sand ejector to pick up the sandy backfill and deliver it very effectively to the trench just a short distance away. I do not have my cost figures on this phase of the job now, but will say that everything was ideal to use the hydraulic backfill procedure. In the case of using the drag line, twice as much dirt had to be moved, and sometimes moved twice in backfilling.



SECTION THROUGH SUSPENDED SEWER

Detailed Sketch of Trench Construction and Suspension of 24 in. C. I. Sewer.

Deep excavation was, of course, less by machine than by hand. By man power it took five men to relay the dirt from scaffold to scaffold during the process of excavating the open cut which was 26 ft. deep to grade. The output of one man was about 5 cu. yards per day. The overall picture shows a difference of 10 per cent in cost, but some items ran as much as 40 per cent higher. Remember, the figures presented herewith will not stand now because manpower efficiency has dropped along with the value of the dollar.

The accompanying pictures taken of this work reveal the true conditions, methods of timbering, forming the foundation, and how the pipe was supported from beams above grade. One picture shows the true finished sheeting ensemble to support the pipe and another reveals one of the troublesome water-boils 26 ft. down in the bottom of the trench. As an example of the instability of the soil in spots, I personally placed a 2 in. x 2 in. x 20 ft. grade pole in one of these water-boils and with little or no effort shoved it down over 16 ft. below the 26 ft. grade level.

Notwithstanding the necessity of replacing over 2300 ft. of the pipe, the sewer has not been out of service more than two weeks, and only at short intervals since 1928 when it was installed.

BREAK DOWN OF COSTS—50 FT. SECTIONS

(1)—By Machine		(2)—By Hand	
One foot Universal C.I. Pipe	$ 4.52	One foot Universal C.I. Pipe	$ 4.52
Timbering 108.6 B.M. @ $40.00	4.35	Timbering	5.13
Excavation	9.28	Excavation	13.00
Backfilling	6.65	Backfilling (Hydraulic)	2.39
Placing Timber	1.60	Placing Timber	3.25
Loose Rock for foundation	.90	Loose Rock for foundation	.90
Supporting pipe from braces	.50	Supporting pipe from braces	.50
Pumping—Etc.	1.50	Pumping—Etc.	1.50
Foreman—Helper	1.00	Foreman—Helper	1.00
Miscellaneous	.80	Miscellaneous	.81
		Pile driver Equipment	1.00
Total	$31.10	Total	$34.00

IMPROVED SOIL PERCOLATION TEST

For Determining the Capacity of Soils for Leaching Sewage Effluents

by

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DISPOSAL of sewage by means of septic tanks together with underground leaching trenches or pits is common wherever sewer systems are not available. Also, the success of this method of disposal depends, more than upon any other single factor, upon provision of adequate soil leaching capacity. The determination of the leaching capacity of a given plot of ground is therefore a very important problem.

In spite of this, relatively little attention has been given to the development of a really reliable and yet practical method for evaluating the rate at which a given soil stratum may be depended upon to leach away septic tank effluent. The common percolation test, as will be noted in more detail in later discussion, is not very reliable. It depends upon measuring the rate of drop of the level of water in a test hole at a time when this rate is rapidly changing. Nevertheless this procedure, which is reported to have been formulated by Henry Ryon of the New York State Department of Public Works in 1927[3], is almost universally used, probably because it is so simple.

The writers have not evolved any new test, but propose to improve the present test by modifying the method for making the rate-of-drop measurements. The object is to obtain measurements which may be subjected to simple mathematical analysis to yield the most dependable result possible.

Proposed Procedure

As in any percolation test, it is first necessary to make auger borings at the site under consideration to determine the types of soil strata present and their extent. Examination of the soils in the various strata, particularly with respect to porosity and organic content, will indicate which stratum or strata may most advantageously be used. Having selected the stratum level to be tested, the test hole, preferably 12 x 12 in. in area and 18 in. deep, is excavated below this level. Often it is necessary first to excavate a larger pit down to the stratum level to furnish working room for digging the test hole. Over the test hole is placed a heavy plank or other object which will not move during the test, to furnish a stable reference point for the liquid level measurements. From this reference point the measurements may easily be made with a calibrated plumb bob.

The test is made by filling the hole with approximately 12 in. of water, the exact distance to the level of water being noted and also the time of this initial filling. Depending upon the rate at which the water level appears to be dropping, a period of time, designated as (Δ t), such as 30 minutes or 60 minutes, is selected as the interval at which repeat measurements are to be made. After elapse of this selected period of time, the distance to water level is measured, the hole then immediately refilled to approximately its original 12 in. depth, and the distance to water level again measured. This procedure is repeated until the rate of drop appears to be leveling off. A total period of testing of not less than 6 hours is recommended. The data are then analyzed as subsequently described.

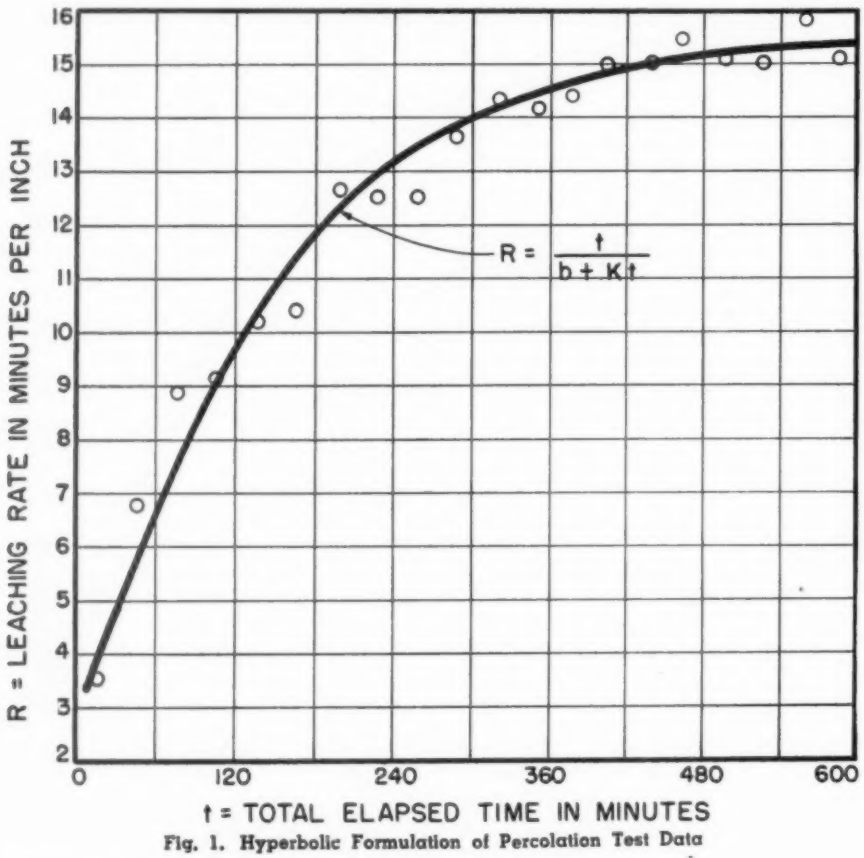


Fig. 1. Hyperbolic Formulation of Percolation Test Data

Mathematical Evaluation

The mathematical evaluation is based on the premise that the ratio, time in minutes for the water level to drop one inch, which we may designate as "R", is constantly increasing during the progress of the test, but at a rate of increase which is constantly decreasing. This is a hyperbolic relationship; i.e., if successive values of R be plotted against corresponding values of t, the total elapsed time in minutes since the initial wetting, the resulting curve will approximate a hyperbola of the type shown by Fig. 1. The equation of this curve may be written

$$R = \frac{t}{b + kt} = \frac{1}{\left(\frac{b}{t}\right) + k} \qquad \text{Eq. 1}$$

where b and k are constants dependent upon the local conditions. What

is really desired to know is the value of R_{max}, i.e., the value which R would eventually reach if the test were continued indefinitely. Then the reciprocal of this figure, $1/R_{max}$, will represent the maximum amount of clean water, in inches per minute, which the stratum under consideration may be depended upon to leach away indefinitely. The problem, therefore, is to determine from the field data the value of R_{max}.

Looking again at Fig. 1, it is noted that R_{max} is actually the asymptote which the hyperbolic curve approaches as t increases to infinity. Considering again Equation (1), it is noted that when t is infinity the value of R will become (1/k). Hence

$$R_{max} = 1/k, \text{ or } (1/R_{max}) = k$$

and the problem now is to determine the value of k. This may readily be done, by tabulating for each successive water application the following values:

1. t = the total elapsed time since the initial wetting
2. Δ t = the elapsed time since the preceding measurement;
3. Δ d = the measured drop in water level during the interval, Δ t;
4. R = (Δ t/Δ d); and
5. t/R = (1)/(4).

Then on a piece of coordinate graph paper plot values of (t/R) as ordinates against values of (t) as abscissae, in the manner shown by Fig. 2. Next a straight line is drawn through the plotted points to fit them as closely as possible. The equation of this straight line is

$$(t/R) = b + kt \qquad \text{Eq. 2.}$$

Since k equals the slope of this straight line, the value of k may be obtained directly from the straight line by scaling its slope.

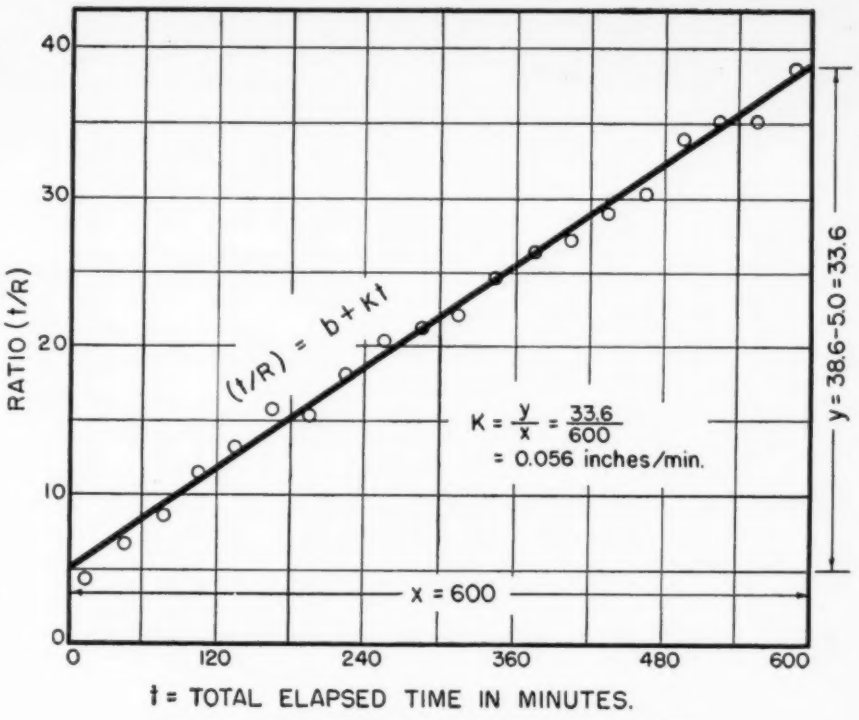


Fig. 2. Straight-Line Formulation of Percolation Test Data

Table I

EXAMPLE OF PERCOLATION TEST IN LOAM SOIL

Time (pm)	H_1 (in.)	H_2 (in.)	Δd (in.)	R (30/Δd)	t (min.)	t/R
1:00	.....	19.00				
			8.33	3.60	15	4.17
1:30	27.33	18.97				
			4.45	6.75	45	6.67
2:00	23.42	18.78				
			3.38	8.89	75	8.43
2:30	22.16	19.00				
			3.31	9.07	105	11.6
3:00	22.31	19.00				
			2.94	10.2	135	13.2
3:30	21.94	18.88				
			2.87	10.4	165	15.9
4:00	21.75	18.79				
			2.37	12.65	195	15.4
4:30	21.16	19.00				
			2.40	12.5	225	18.0
5:00	21.40	18.91				
			2.40	12.5	255	20.4
5:30	21.31	19.13				
			2.19	13.7	285	20.8
6:00	21.32	19.07				
			2.09	14.3	315	22.0
6:30	21.16	18.94				
			2.13	14.1	345	24.4
7:00	21.07	19.00				
			2.09	14.3	375	26.2
7:30	21.09	19.00				
			2.00	15.0	405	27.0
8:00	21.00	19.00				
			2.00	15.0	435	29.0
8:30	21.00	18.94				
			1.94	15.5	465	30.0
9:00	20.88	19.00				
			2.06	14.6	495	33.9
9:30	21.06	19.06				
			2.00	15.0	525	35.0
10:00	21.06	18.94				
			1.89	15.9	555	34.9
10:30	20.83	19.05				
			1.98	15.1	585	38.7
11:00	21.03	.....				

Notes: Δt = 30 minutes.
H_2 = Distance from reference mark to water level immediately after each filling of test hole.
H_1 = Distance from reference mark to water level at end of each (Δt) period.

Example of Problem

Table I lists the data obtained from an actual field test, together with the necessary computed data. Fig. 2 shows the plotted curve, and the determination of k. (These same data are the basis for the points plotted in Fig. 1.)

In the event the plotted points do not indicate a straight-line type of curve, then it may also be necessary to plot values of R against t, in the manner indicated in Fig. 1. This will illustrate the nature of the rate of variation in leaching. Examination of this curve may show that there is a lag in time before the typical hyperbolic leaching phenomenon becomes established. In this event, the beginning of the test period should be considered shifted to that time when the hyperbolic curve begins to form. Corresponding new values of t and of t/R should be computed and plotted to obtain straightline curve from which k may be scaled.

Determining Sewage Effluent Percolation Rates

Having determined the value of k, or the maximum rate at which the stratum will continuously leach away clean water, it is necessary to reduce this figure by multiplying it by a suitable factor, "F", to account for the fact that septic tank effluent is not clean water but contains organic sewage materials. Notwithstanding the treatment in the septic tank, these materials retain some of their soil-clogging properties. The

value of F will therefore depend upon the quality of the effluent to be disposed of by leaching. It is probably a function also of the magnitude of the leaching rate for clean water. As yet there is little reported data on the basis of which definite values of F may be computed, but for conservative design a value of 50 per cent is at present believed best for ordinary installations. In other words, the amount of sewage effluent which may be leached away is approximately one-twentieth of the amount of clean water.

Discussion

The proposed method is believed to furnish a more reliable basis for engineering design than does the common percolation test, because the result obtained is based on all of the measured field data obtained over an extended period of time. In the usual procedure for making the percolation test, the excavated test hole is generally filled once and the water allowed to seep away, then the hole is again filled and the time noted for the water to drop one inch. The inaccuracy of this method is easily seen by reference to Fig. 1. The critical measurement is being taken at some point in the initial section of the hyperbolic curve. Not only is the rate of drop changing rapidly in this section, but it is not even known where the point is, which corresponds to the measurement.

The proposed procedure does not eliminate the deficiencies inherent in the soil percolation test. But it may "make the most" of this test by providing a reliable means for evaluating the data obtained. The procedure therefore should make possible also the accumulation of more accurate comparative data as to the relative rates of percolation of clean water and sewage effluents.

Reference

(1) Federick, J. C. Solving Disposal Problems in Unsewered Areas. *Sewage Works Engineering*, June (1948).

CHART TO DETERMINE ACRES IN PLOT OF GROUND

Here is a chart which many a water or sewage works engineer will find handy for quickly determining the acreage of any rectangular area, regardless of how long or wide.

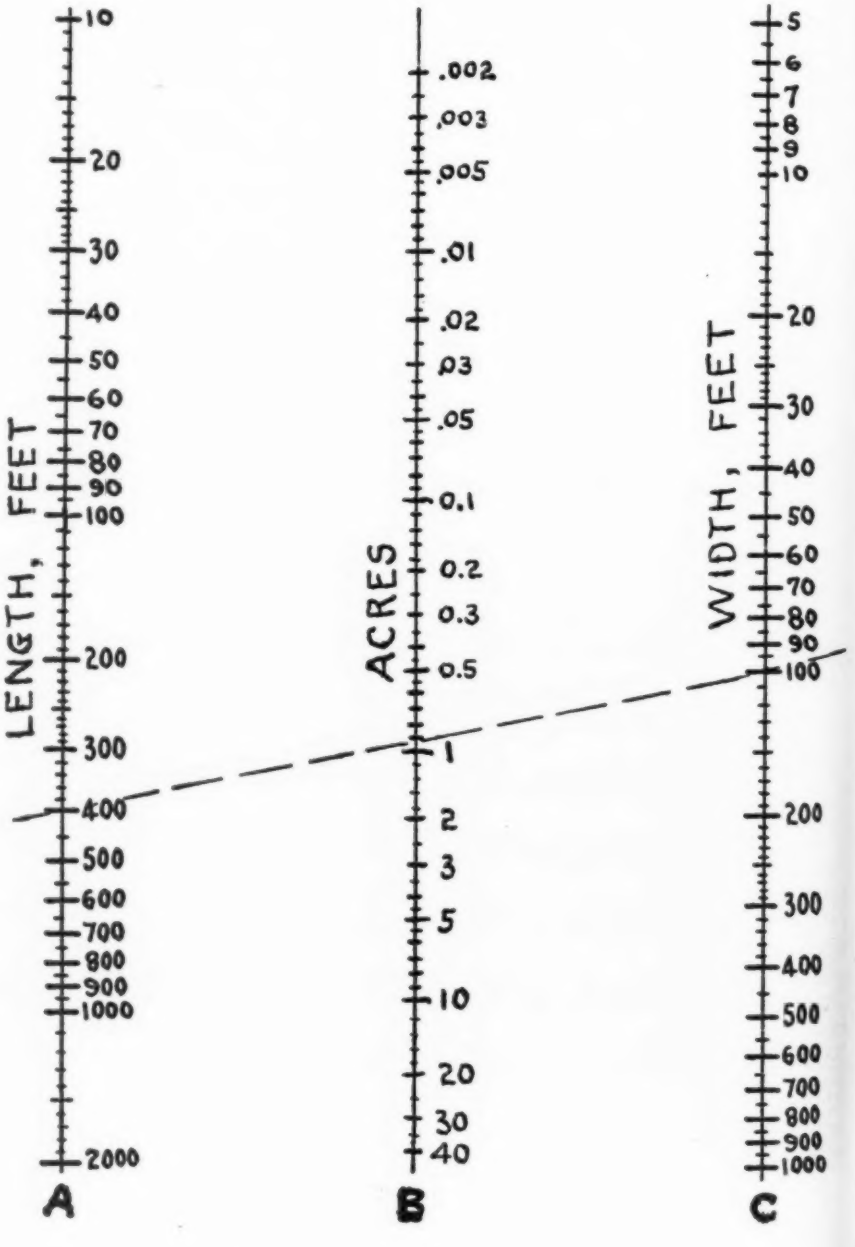
For example, the dotted line drawn across the chart shows that if the area in question is 400 feet long (column A) by 100 feet wide, (column C), the acreage is slightly over 0.9. Estimating with the eye you can see that 0.92 acre is about right.

The same dotted line would also show that if the area is 4,000 feet long by 100 feet wide, it would amount to about 9.2 acres.

If the area is 40,000 feet long by 100 feet wide, it contains about 92 acres.

And so on. In other words, add as many ciphers to the answer in column B as the sum of ciphers or digits added in columns A and C.

Experiment with the chart a bit and you will soon appreciate how convenient and valuable it is.



Contributed by W. F. Schaphorst, M. E., Newark, N.J.

Learned Syphon Principle The Hard Way

John Mackie set up a collapsible 3,000 gal. Army surplus water tank for use as a pool for the kiddies.

He filled the tank from the garden hose but made the mistake of leaving the nozzle end in the canvas tank while he disconnected the hose at the sill-cock and dropped the end into the cellar through the window.

Next morning Mackie found the entire 3000 gallons of water in his cellar, and learned something about the syphon principle.

PRECONDITIONING AND DIGESTION OF SEWAGE SLUDGE

The Second of a Series of Articles from the Operator's Viewpoint

Secondary Sludge Return; Measuring and Sampling Raw Sludge

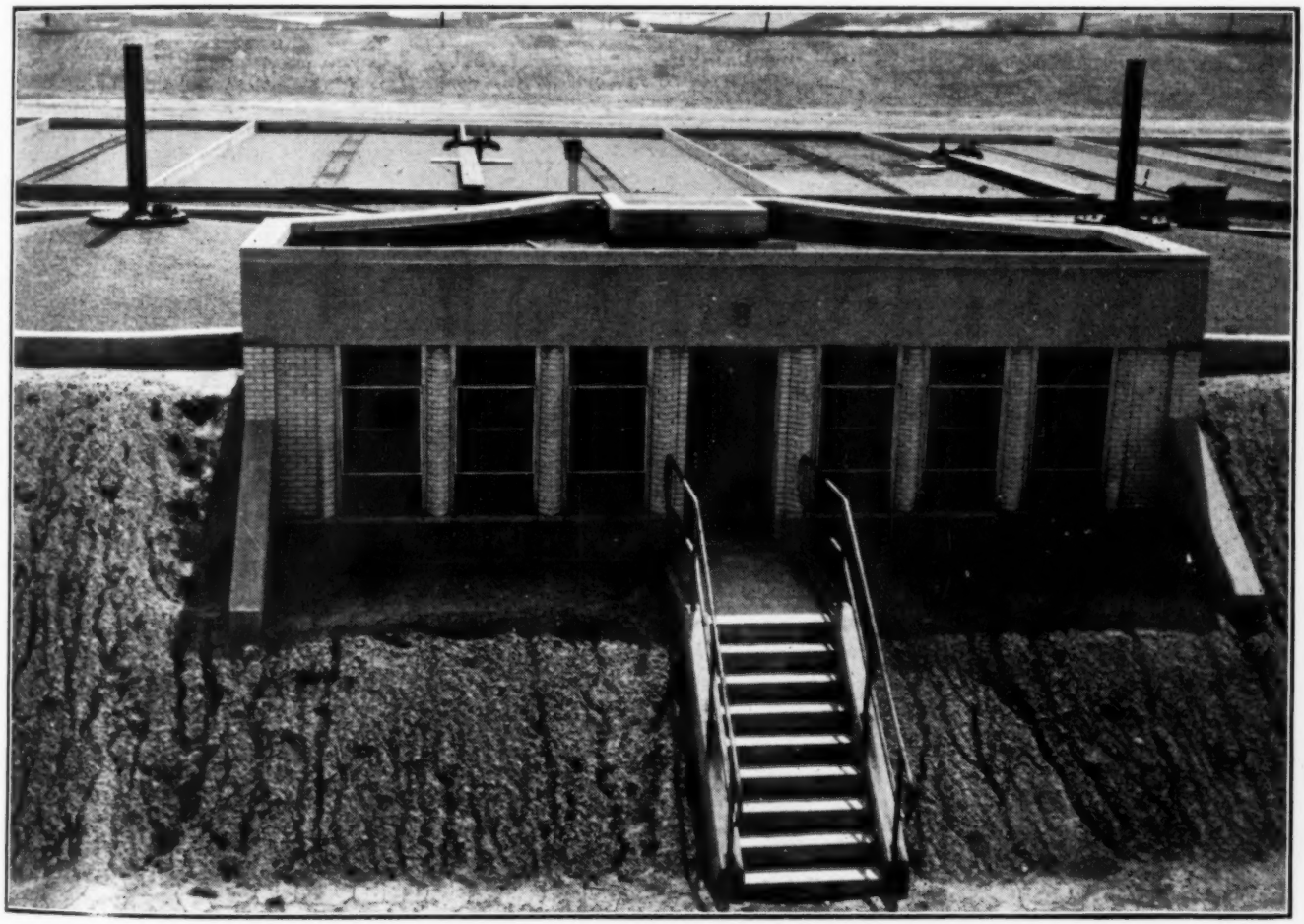
by

T. R. HASELTINE
THE CHESTER ENGINEERS
PITTSBURGH, PENNA.

The Author

AS PREVIOUSLY noted, excess activated sludge usually contains from 98 to 99.5 percent moisture, or even more. If satisfactory digestion is to be obtained, it is almost imperative that the moisture content be reduced before those solids enter the digestion chamber. Fischer[7] was the first to hit upon the idea of pumping the excess activated sludge back to the raw sewage and allowing those solids to settle out with the heavier raw solids in the primary basins. His experience was obtained at Salem, Ohio, in 1930. Since then this procedure has become almost universal practice at activated sludge plants. My first experience with this procedure was about a year later at Salinas, Calif. Despite the general acceptance of this practice, it has numerous disadvantages.

In 1933[8] I stated, "That although the wasting of excess activated sludge to the primary clarifier greatly reduces the volume of sludge to be digested and hence improves the functioning of the digestion process, it increases the solid content and oxygen demand of the settled sewage and thus increases the cost and difficulty of operating the activated sludge process. The practice transfers difficulties from sludge digestion to the treatment of the liquid portion of the sewage. The



Digester Control House—Two Digestion Tanks with PFT Floating Covers
(Sludge drying beds in background—Uniontown, Pa.)

Close-up of Floating Cover Digestion Tanks
(Glass covered sludge drying beds in background—Butler, Pa.)

degree to which this tendency will be noticed depends primarily upon (a) the amount of sludge wasted, (b) the rate at which it is wasted, and (c) the design of the primary settler."

In 1944 Donaldson[6] stated that, "Experience in New York City indicates that the rather common practice in smaller plants of concentrating excess activated sludge by wasting return sludge to the head of the primary tanks is not to be recommended unless the primary retention period is two hours or more. Shorter retention periods are apt to result in higher suspended solids in the effluent than in the raw sewage influent. Moreover, the septic character of the settled sewage is likely to be disturbing to the subsequent aeration process."

Regardless of whether this method of concentrating activated sludge ahead of digestion is good or bad most operators of activated sludge plants have no alternative and so must use it. The following three rules are laid down for them in order that they may get the best results possible with the procedure.

1. *Waste a little sludge every day instead of wasting a lot on some days and none at all on others.* This necessitates determining the suspended solids in your areation tanks daily. Because of possible variations in sludge index this determination must be made gravimetrically or by centrifuge, not by simple settling in a liter graduate.

2. *The rate of wasting sludge to the primary basins should be as uniform as possible throughout the 24 hours; don't waste at a high rate for just a few hours a day.* To accomplish this it is necessary to be able to see the flow of waste sludge and to inspect it at frequent intervals. Simple counting of turns on a gate valve does not give uniform or satisfactory results because the valve is usually just "cracked" and subject to clogging. If a V-notch weir or other means of measuring the rate of wasting sludge can be installed, it will greatly facilitate the application of both of these rules.

3. *Carry an appreciable depth of sludge (at least 2 ft.) in the primary sedimentation basins.* Pump sludge from those basins to the digesters at low rates for short periods at frequent intervals or, if possible, continuously, but still maintain the 2 foot sludge depth.

The first two rules are of general application. If rule 3 is followed, it will improve digester performance but may interfere with the activated sludge process and, therefore, the operator must decide which process is most critical in his particular plant. If he has, or can devise, a sludge decanting tank, as was previously discussed, he may be able to disregard this rule entirely and still not interfere with digestion.

While, as previously pointed out, there are certain objections to wasting excess activated sludge to the primary sedimentation basins, I know of no objections of disposing of humus, or trickling filter, sludge in this manner. It relieves the operator of the necessity of paying close attention to the moisture content of the sludge pumped from his final tanks and makes it possible to pump those tanks long enough, and at a high enough rate, to insure that they will be free from sludge. If excess water is also returned to the primary tanks along with the sludge, it only results in "recirculation", which is the chief difference between the so-called standard trickling filter plant and the newer "high rate" filter plants. The trickling filter sludge is initially much higher in solid content than the excess activated sludge and, therefore, its return to the raw sewage instead of delivery direct to the digestion compartment will not effect such a reduction in total volume of sludge going to digestion, but, at least, it does not increase that volume.

In many of the older Imhoff tank trickling filter plants the piping was arranged so that secondary sludge was delivered directly to the gas vents or digestion compartments of the Im-

Table IV.

Comparison of Various Methods of Calculating Raw Sludge Composition at Butler, Pa.

Period in 1940		Total Solids in Raw Sludge Calculated From			Volatile Solids in Raw Sludge Calculated From		
From	To	Sludge Volumes and Total Solids Tests	Sewage Flow & Total Susp. Solids Tests	Sewage Flow & Total Residue Tests	Sludge Volumes and Vol. Solids Tests	Sewage Flow & Vol. Susp. Solids Tests	Sewage Flow & Volatile Residue Tests
Feb. 4	Feb. 24	2480	1987	1780	1813	1617	1483
Feb. 25	Mar. 23	2265	1383	1025	1640	1100	635
Mar. 24	Apr. 20	1563	1213	1090	1085	960	1043
Apr. 21	May 18	1860	2185	1990	1368	1643	1383
May 19	June 15	4842	4526	3687	2520	3270	1670
June 16	July 13	3110	3616	3298	2131	2552	2151
July 14	Aug. 10	4060	3326	3273	2704	1992	2363
Aug. 11	Sept. 7	3678	3753	.....	2618	2813	.....
Sept. 8	Oct. 5	3750	3595	3605	2758	2773	3145
Oct. 6	Nov. 2	3935	3329	3488	2898	2978	2608
Nov. 3	Nov. 30	3466	3108	3106	2610	2275	3174
Averages		3183	2911	2634	2195	2179	1966

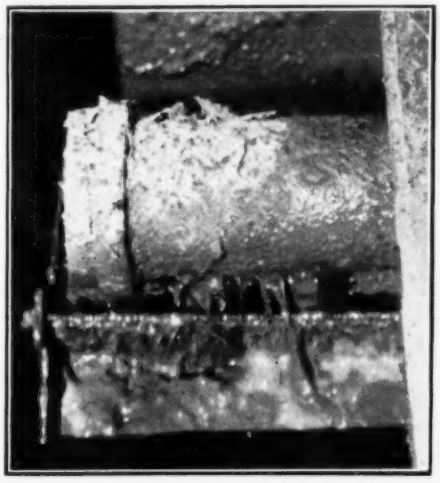
hoff tank rather than to its sedimentation chamber. This was a mistake because the introduction of any liquor directly to the gas vents or digestion compartments causes a corresponding upward flow through the slots, which definitely interferes with sedimentation. If you are operating such a plant, it is strongly recommended that you make the relatively minor changes necessary to deliver the secondary sludge directly to the flowing-through compartment of the Imhoff tank.

Measuring and Sampling Raw Sludge

The foregoing discussion about covers the principal phases of conditioning raw sludge prior to digestion. It may be found desirable to add lime to the sludge before it enters the digester and, at some plants, the sludge is heated ahead of digestion. While, technically speaking, those may be steps in sludge conditioning, I think they can be more clearly discussed in connection with the operation of the digestion process.

To condition sludge ahead of digestion, or to operate the digestion process intelligently, it is necessary to know the volume and composition of the raw sludge. The measurement of undigested sludge is one of the most difficult metering jobs in all hydraulics. Weirs may be used for excess activated sludge, but are entirely unsuitable for other sludges. The high solid content and the nonhomogenous character of those solids gives rise to frequent clogging troubles with most, if not all, commercial metering equipment on the market. Because of this fact, few sewage plants have raw sludge meters.

In 1936 Sperry[9] developed a tipping bucket sludge meter at Aurora, Illinois. Since then his idea has been adopted at a few other plants including Butler, Pa. The "meter" consists of an inverted, isosceles triangular tank of any desired width mounted on a single horizontal shaft through the vertex of the triangle. A central partition divides the tank into two compartments. Sludge is fed to the "meter" through a slotted pipe parallel to the shaft. It flows into one compartment until the accumulated weight becomes great enough to tip the tank and bring the other compartment under the slot so that it may fill while the first compartment is emptying. A simple counter records the number of the dumps; it is then a simple matter to convert this figure to cubic feet or gallons if the volume of the compartments is known. I believe this is the best type of raw sludge meter yet developed. However, it must be located above the digestion tank, housed



Interior of Tipping Bucket Sludge Meter—Butler, Pa.

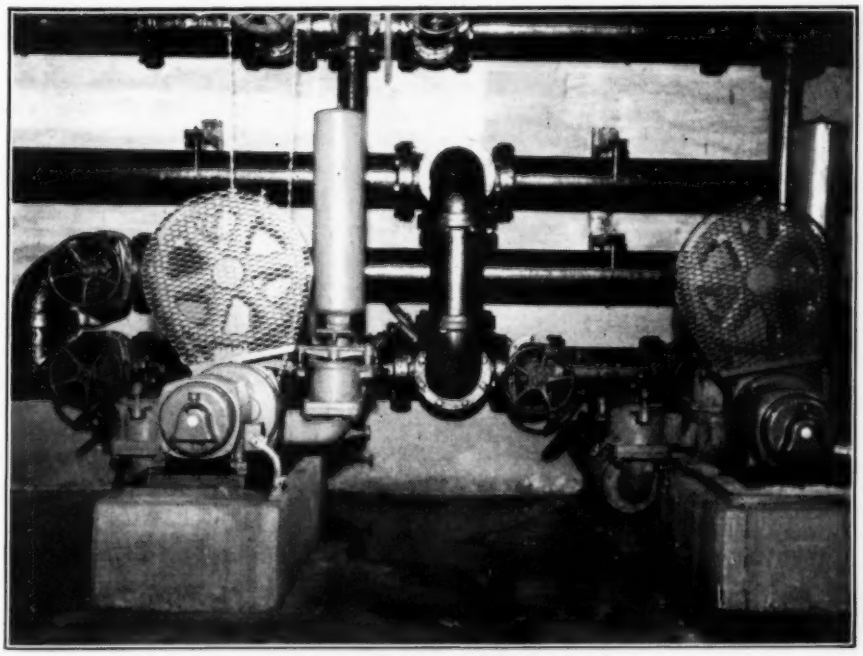
to protect it from freezing and made very strong to withstand the repeated shocks. As a result, it is quite expensive and so has not been generally adopted.

If a sludge decanting tank, as previously described, is used, the volume of sludge, both before and after decanting, can be measured by simply measuring the depth in that tank and multiplying by the cross sectional area of the tank. Actually, since the total tank depth is known, it is easier to measure the distance from the top of the tank down to the sludge surface than it is to measure the depth of sludge. A measuring stick can be marked off in such a manner that the operator can measure down to the sludge surface with it and read off the volume of sludge directly without resorting to repeated multiplications and possible arithmetical errors.

Many plants have neither sludge meters or decanting tanks. In such instances a simple counter can be rigged on a plunger type sludge pump in such a manner that the number of strokes will be counted. The bore and stroke of the piston can be measured and from these figures and the number of cylinders the volume of sludge pumped can be estimated. Be sure and measure the stroke on *all* pistons and check them frequently to avoid possible slippage of eccentric adjustments. Sludge volumes measured this way are only approximate and err on the high side because, as any operator knows, rags, sticks, or similar articles frequently become logged in the pump valves and so its delivery falls off or stops completely.

In addition to knowing the volume of sludge pumped to the digestion process, it is also essential to know the weight of volatile and mineral solids delivered to the process. Methods for determining the total and volatile solid content of sludge samples are adequately described in "Standard Methods." However, no analysis is any better than the sample upon which it is run. It is even more difficult to collect a representative sample of raw sludge than it is to measure the volume of such sludge.

Perhaps the chief merit of the tipping bucket meter previously described is that by strategically locating a 2-in. pipe and ell, or similar collecting line, a small sample of each dump can be collected each time the bucket dumps. These samples can be conducted to a suitable container or sink with plug. At the end of the pumping



Sludge Pumps and Piping

(Note valves to give flexible operation—Sampling can be done from discharge lines.)

period the contents of the container can be stirred up and a smaller sample taken for analysis. At Butler it is routine practice to collect such samples each time sludge is pumped, i.e. three times a day. The size of those samples are varied in proportion to the volume pumped. These samples are poured into a larger container and kept in the refrigerator. Once a week the accumulated composite of 21 samples is analyzed.

I know no other way of getting as representative a sample of raw sludge, regardless of the effort expended. However, an approach to such a sample could be obtained by having the sludge pump operator collect a uniform sized-sample of sludge from the pump discharge every two minutes, five minutes, ten minutes, or some similar short period of time. These individual samples may be composited for weekly analysis. The more frequently the individual samples are collected, the more representative will be the analysis. Obviously, this is a very time-consuming procedure, as the pump operator can do nothing else all the time the pump is operating. As a compromise I have used this method for only one day a week. If such a scheme is followed conscientiously, it will, in time, give some idea of the sludge characteristics but it does not give results of sufficient accuracy to intelligently study short term variations in digester performance.

Because of the difficulty of sampling raw sludge it is frequently better to calculate its solids content from sewage flow measurements and suspended, or total, solids determinations from the analyses of the sewage at various stages of its travel through the plant. To be of value the sewage must be sampled at frequent intervals around the clock (say once an hour) and the size of the individual samples must be proportioned to the sewage flow. The calculations for a primary sedimentation basin, or for a final basin following trickling filters, would be as follows:

Total (or volatile) solids in sludge $= 8.34 \times$ flow in mgd. $\times$ difference in total (or volatile) suspended solids (or residue on evaporation).

For an activated sludge plant in which the excess activated sludge is returned to the primary basin the samples of inflow to that basin must include the excess sludge, or as an alternative the solids in that sludge may be calculated from independent flow measurements and analyses made on it.

Theoretically, if all flow measurements, sampling procedures and analyses are perfect, the calculations from sludge measurements should agree with those from sewage measurements. Actually such ideal conditions never prevail and so the various methods seldom agree. Table IV shows a comparison of the various methods that was made over a 44-week period at Butler in 1940. Each figure in that table represents the average of four weekly calculations. For any one week the differences between the three methods were generally greater than the averages shown. At Butler the raw sewage samples must be collected from a manhole which makes sampling difficult. Because of that fact, as well as because we have the tipping bucket sludge meter and automatic sampler, we feel that the figures calculated from sludge measurements are the most accurate. At some other plant, the reverse might be true. Table IV shows that the results calculated from residue determinations were the most erratic—I don't know why. For the past seven years that determination has been discontinued at Butler.

S. C. (Sandy) Martin Heads U.S.P.H.S. Great Lakes Office

According to an announcement by Asst. Sur. Gen. Mark D. Hollis, Chief of Engineering Activities, U.S.P.H.S., appointment has been made of Sylvan C. (Sandy) Martin as Senior Sanitary Engineer to head the Great Lakes Drainage Basin Office of the Division of Water Pollution Control.

The Chicago office located at 225 West Jackson Blvd. is the third of fourteen proposed river basin offices being established to coordinate the federal water pollution control activities with state, interstate, and local agencies as provided in Pub. Law 845.

Martin, who is a native of Michigan, and holds a B.S. and M.S. in engineering from Ohio University, has formerly worked with the U.S. Engineers and the Illinois State Division of Sanitary Engineering. He served in the Sanitary Corps during the war. Since July, 1947, Mr. Martin has been Assistant Editor of *Sewage Works Journal* on the staff of the Federation of Sewage Works Associations. He is a member of the A.S.C.E., N.A.P.E. and F.S.W.A.

Sewer Service Charges

The paper delivered by Henry W. Taylor, New York City consulting engineer, on the subject of Sewer Service Charges in the New York Metropolitan Area, is available for distribution by the American Public Works Assoc., New York-New Jersey Chapter, I. J. Casey, Jr., Town Engineer, Irvington, N. J., president.

Mr. Taylor's chief point is that sewer service charges must be based not only on the use of the sewers, but also on "readiness to use" and compares the latter factor with the fire protection charge used in water rates.

A copy (27 pages) may be obtained for 50 cents by writing I. J. Casey, Jr., Town Engineer, Irvington, N. J.

W. E. Spencer, Plant Supt., Merchantville, N. J.,

Succeeds the Late Joe Campbell

Walter E. Spencer, well known water works operator from Merchantville, N.J., and long-time secretary of the South Jersey Water Superintendents' Assoc., has been appointed to the position of Superintendent of Water, of the Merchantville-Pennsauken Water Commission at Merchantville, N.J.

Mr. Spencer succeeds the late Joe E. Campbell who had held the position for the past 36 years. Mr. Spencer had been associated with Mr. Campbell as assistant superintendent for most of that time. Both men have been prominent in the water works profession as members of the N.J. Section of the A.W.W.A. and of the South Jersey Assoc. of Water Supts.

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SPECIAL CHARGE FORMULAS FOR INDUSTRIAL WASTES IN MUNICIPAL SEWAGE

(A Review)

by
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IN MODERN municipal sewage treatment, the trend is to establish formulas for equitable service rates for industries discharging excessive waste loads to municipal sewage works. In reviewing this subject in the June, 1946, issue of *Industrial & Engineering Chemistry*, Harold R. Murdock[1] said, "the rental of municipal sewage systems can become a convenient means for industry to dispose of its liquid wastes", but he pointed out that "equity to all concerned in disposition of waste products is essential."

The earliest writers recommending sewer rentals and the need for providing charges for wastes of excessive strength were Marsten of Metcalf and Eddy, and F. H. Waring of the Ohio State Health Department. The earliest agreements toward this end were those wherein industry has paid part of the construction costs of sewage treatment plants handling the wastes. Perhaps the most notable example was the city of Cedar Rapids, Iowa. Most of the agreements of this type have been based on yearly or negotiated charges.

Buffalo Formula

In February, 1943, a new type of service charge was introduced at Buffalo, N.Y. This was the "Buffalo Formula" in which industry was charged for excessive wastes on the basis of volume, and concentration of waste. As reported by Symons and Crane in the Mar., 1944, issue of *Water Works and Sewerage*[2], the following formula is used for calculating the charge applied:

$$R = FP_c(C - N_c) + FP_s(S - N_s)$$

where R = rate of special charge, cents/1,000 cu. ft. of waste volume.

F = factor for converting the ppm. to lb./1,000 cu. ft.

P_c = contract price of chlorine, cents/lb.

C = concentration of chlorine demand of waste, ppm.

N_c = normal dry weather chlorine demand of raw sewage, ppm. of sewage received at treatment works.

P_s = cost in cents of chemicals for sludge conditioning, and of power for solids disposal resulting from 1 lb. of suspended solids received in raw sewage at treatment works.

S = concentration of suspended solids in waste, ppm.

N_s = normal grit-free suspended solids of raw sewage as received at treatment works, ppm.

The factor P_c may vary from year to year according to the contract price for chlorine, and the factor P_s may vary according to the price of chemicals and power involved in the disposal of solids, as determined from operations for the previous year or previous two years. The factors C and S may be established by analysis (periodic or otherwise) to obtain average concentrations to be applied for any agreed length of time.

Average sewage results at Buffalo are 5.6 ppm. chlorine demand and 157 ppm. suspended solids. The special charge for 1000 cubic feet of waste amounts to 0.136 cent for each ppm. chlorine demand and 0.00305 cent for each ppm. suspended solids determined by the sewage analysis. It has not appeared economically feasible to apply a special charge when the rate is less than 1 cent per 1000 cubic feet of waste volume.

The "Buffalo Formula" is the final result of simplification of a great many factors. For example, the effect of dilution and possible reactions of an industrial waste with sewage during the course of passage through the interceptors is considered and determined by analyses, after which the formula is applied.

A reference to the original article[2] will indicate that this formula was developed to fit the specific conditions existing at Buffalo, where prechlorination, sludge digestion, and sludge dewatering and incineration only are practiced. The "Buffalo Formula" makes no charge for the volume of the waste per se. The rate is based per thousand cubic feet of volume, but is a rate only for chlorine demand and suspended solids above the normal average load existing in the sewage. Inasmuch as the sewer rental system in Buffalo charges according to volume, it was simpler to prepare this formula for charge on the volume basis.

The application of these charges has been successful so far in Buffalo. When questions arise, cooperative and friendly negotiations have solved the problem.

New Brunswick, N. J.

In February, 1944, New Brunswick, N. J., passed an ordinance based on the premise that all wastes should be treated at the municipal plant without pretreatment by industry. The ordinance stated: "The charges for factory effluents or industrial wastes discharged into the city sewers or tributaries thereof shall be fixed and determined according to flow, suspended solids, and chlorine demand, according to the following schedule of rates: $22.00 per million gallons, $5.00 per ton of sludge, and $5.00 per 100-pound chlorine demand." Chester Paulus[3], mayor of New Brunswick, reported in July, 1944, that "if industrialists are willing and do cooperate, most industrial wastes can be handled in adequately designed sewage treatment plants constructed for the treatment of domestic sewage; but in this cooperation the industrialists must be prepared to pay their full share of the cost of the plant enlargement and plant operation."

The Wright Formulas

Another approach to this matter of industrial waste formulas was proposed by Dr. S. R. Wright[4], Head of the Civil Engineering Dept. of the Univ. of Texas. Dr. Wright wrote as follows:

"There are two methods of handling charges for industrial wastes. One method places the responsibility of pretreatment of sewage on the industry so that the industrial wastes entering the city's system will come within prescribed standards of strength, and the industry then would pay for sewerage service on a volume basis at the regular rate charged to other customers. Under the other method the city receives the raw sewage from the industry and adjusts the rate to compensate for strength of the sewage.

The method requiring industries to pretreat their wastes has many advantages. The city is able to place all customers on an equal footing as far as charges are concerned. Strong industrial wastes are by-products of industries and the cost of treating these wastes to bring them to the strength of normal sewage should be a part of the cost of production of the industry's finished product. Shock loads from strong industrial wastes may upset the bacterial action in the sewage treatment plant. While such a requirement of pretreatment by industry of its wastes would be very desirable from the standpoint of the city, it is not always practical. The wastes from certain industries might be slightly stronger than the prescribed standard of normal sewage but would not be sufficient to justify a treatment plant. In other industries it may be undesirable or impossible to place the pretreatment facilities at the plant site. The owners of large plants often are influential in local politics and may make it difficult for the local city administration to enforce such regulation.

"If pretreatment of industrial wastes is not required of industries, some adjustment should be made in the rate schedule to compensate for the concentration of the sewage.

" . . . Wastes from establishments that contribute wastes of approximately the same concentration as sanitary sewage are not usually classed as industrial wastes. . . . It is well to provide that an industry must make application for sewerage service and in many cases the regular sewage rate can be applied; but for those industries with wastes of an abnormal character, a special study of volume and concentration can be made and an agreement can be reached with the industry relative to the charges before service is granted."

Where primary treatment only is afforded, Dr. Wright recommends that the basis of special charge be suspended solids, and if chlorination is used, suspended solids and chlorine demand should be the basis of charge, while if complete treatment is afforded, then the basis of charge should be suspended solids and B.O.D.

Dr. Wright assumes that 50 per cent of the suspended solids will be removed in primary treatment alone. "In the case of industrial waste, since the added cost of operation, due to the concentration is the added cost of treatment, it will be necessary to estimate the ratio of the annual cost of operating the treatment plant to the total

amount cost of operating the entire sewage works system. If the charges are intended to pay all costs, the fixed charges should be included in both annual costs, but if the charges are to defray only the operating expenses, then the annual costs used to determine this ratio will be only the operating expenses of the treatment plant and the total operating expense of the system. The added cost of treating a thousand gallons of industrial waste will be due to the excess solids contained by the waste above that of normal sewage which ordinarily will be about 150 parts per million. But where primary treatment is the only treatment involved, about half of the total suspended solids will pass off with the effluent and will not add to the cost of treatment. When charges are to be determined for a given industry several tests for suspended solids should be made on the industrial waste in question. With the above information, a factor to multiply the regular volume rate by, to adjust for concentration, can be determined. Expressed as a formula this factor would be:

Formula:

$$F = 1 + \frac{.5R\ (S - 150)}{150}, \text{ or}$$

$$F = 1 + \frac{R\ (S - 150)}{300}$$

"Where F is a factor by which the regular volume rate is multiplied, R is the ratio of the annual cost of treatment to the total annual cost of the entire system, and S is the suspended solids, expressed in parts per million by weight, in the industrial waste in question. An example will illustrate. Assume that the cost of the primary treatment is $20,000 per year, and that the annual cost of operating the entire system is $50,000. Then R in the above formula becomes 0.4. One industry contributes a waste containing a suspended solids content of 750 ppm. Substituting in the above formula, F becomes 1.8. In fixing the charge for this industry the regular rate per thousand gallons should then be multiplied by 1.8, or in other words, this industry should pay 1.8 times as much per unit volume as a user of the system who contributes only domestic sewage."

This formula works equally well and equitably for industries whose suspended solids input is far below the average. Dr. Wright suggests that where the factor F is between 0.9 and 1.1 (i.e. suspended solids of 75 to 225 ppm.) it should not be necessary to make any adjustment in the regular sewage rate.

When complete treatment is afforded, Dr. Wright assumes the average B.O.D. of domestic sewage to be 200 ppm. and adds another term to the formula to take into account the secondary treatment in the following manner: "The added cost due to a heavy organic content would be

$$\frac{\text{B.O.D.} - 200}{200}$$

times the normal organic load. But since approximately one-third of the B.O.D. is usually removed in the primary treatment the added cost due to the extra load on the secondary treatment is due to only two-thirds of the total organic load in the industrial waste. Therefore, the factor by which the volume rate must be multiplied where complete treatment is involved may be expressed as:

$$F = 1 + \frac{R\ (S - 150)}{300} + \frac{2R\ (\text{B.O.D.} - 200)}{3 \times 200}$$

Which can be simplified to:

$$F = \frac{300 + R[(S - 150) + (\text{B.O.D.} - 200)]}{300}$$

where F is the factor by which the volume rate is multiplied, R is the ratio of cost of treatment to the total cost of operation of the sewerage system, S is the suspended solids in the industrial wastes expressed as ppm. and B.O.D. represents the 5-day B.O.D. in ppm. of the industrial waste. As an example, let R be assumed to be 0.6. A local packing house discharges a strong solid content of 1,000 ppm. and a 5-day B.O.D. of 3,000 ppm. Under these circumstances F would be 8.3 times the unit rate for ordinary domestic sewage. On the other hand, an industry similar to the one quoted in the preceding example which discharges relatively clear water into the sewers could receive an adjustment in its rate schedule."

In this case too, Dr. Wright recommends no adjustment of the normal rate when the factor F is between 0.9 and 1.1; under which condition the B.O.D. could vary 100 ppm. or more without affecting the actual rate charged.

Dr. Wright concluded with the thought that it is desirable to base industrial sewage rates on volume of water actually discharged to the sewers, and to make the adjustment on the concentration basis even though some other basis of charge is used for the domestic sewage.

The formulas suggested by Dr. Wright are a variation of the principle adopted in the Buffalo Formula, namely that industry should pay an extra service charge for any load it imposes on the treatment plant over and above the load normally to be expected in the same volume of domestic waste.

California Formula

There exists a very excellent report on this subject prepared by the 1945 Committee on Industrial Wastes of the California Sewage Works Association. That report was reprinted on page 503 in the May 1946 issue of *Sewage Works Journal*.[5]

For persons who are faced with the problem of handling industrial wastes in municipalities we heartily recommend a thorough study of that California report. That report includes a survey of methods used in handling industrial wastes, a listing of factors to be evaluated in arriving at a charge or a basis of charge for handling industrial wastes, as well as a discussion of public policy and examples of existing formula or ordinances for charges. In addition, the report includes a thorough discussion of the various factors affecting the following: Chambers of commerce, industrial management, sewage works operations, local government agencies, state agencies, and sanitary engineers and consultants.

Specifically that report lists the following: "Factors to be Evaluated in Arriving at a Charge, or Basis of a Charge, for Handling Industrial Wastes."

"A. Type of sewage treatment plant or disposal method used in a given municipality:
   1. Discharge into stream—dilution only.
   2. Preliminary treatment—screening, de-gritting, de-greasing.
   3. Primary treatment—sedimentation and digestion.
   4. Secondary treatment:
      (1) Chemical precipitation.
      (2) Biological treatment—trickling filters.
      (3) Biological treatment—activated sludge.

"B. Designed volume of plant and the present percentage of volume used in treating the city sewage.

"C. Capacity available in plant design for absorbing industrial wastes.

"D. Type and character of wastes to be handled:
   1. Volume.
   2. Suspended or settleable solids.
   3. B.O.D.
   4. Toxic or destructive material or inhibitive elements present.

"E. Policy of city as regards industry:
   1. Whether city is obligated or committed to accept wastes.
   2. Whether they feel it expedient or politic to handle the wastes of certain plants.
   3. Whether the present plant will handle any excess capacity or whether new units or additional treatment will be required if wastes are included.
   4. Amount of taxes contributed by industries to general city funds.

"F. Basis of charges for handling industrial wastes:
   1. Charging for entire load contributed by industrial plant on basis of—
      (1) Volume.
      (2) Suspended or settleable solids.
      (3) B.O.D.
      (4) Chlorine demand.
   2. Charging for excess loads contributed by industry in relation to composition of normal sewage of city:
      (1) Excess volume.
      (2) Excess suspended or settleable solids.
      (3) Excess B.O.D.
      (4) Excess chlorine demand.

"G. Fixed charges:
   1. Whether industrial plants should pay proportional charges of operation, such as interest on plant investment, amortization, obsolescence, etc.

"H. Charges for maintenance:
   1. Whether the industry shall be charged for its proportional share of maintenance charges on large sewerage systems, where these are recorded separately from sewage treatment plant costs.

"I. Initial cost of plant:
   1. Whether, in case an existing sewage treatment plant accepts industrial waste, the industry should be charged for its proportional part of the initial cost of the plant, on the basis of volume or other constituent contributed.
   2. Whether industry should pay the entire cost of new units or for additional degrees of treatment required to treat its wastes, or pay only its proportional part as represented by its ratio of volume or load to the city's volume or load.

"J. Rebate or reduction for taxes paid to city by industry:
   1. Whether the total amount of taxes paid by an industry should be deducted from the total of any charge arrived at for handling its wastes.
   2. Whether only the proportional part of the taxes paid by an industry as represented by the proportion of the city taxes used for sewage treatment and maintenance shall be deducted from the total of any charge arrived at for industry.

"K. Adjustment for beneficial wastes discharged by an industry. In some

cases an industry may discharge a waste which would:

1. Tend to flush sluggish sewers and keep them from clogging or building up sludge banks.
2. Neutralize wastes contributed by other industries to the point where the flow would then not be harmful to structures or inhibitive to processes.
3. Precipitate sulfides from the sewage.

"L. Adoption of a standard of maximum strength of sewage to be admitted to sewers and treatment plants:

1. Whether a maximum limit of suspended solids, settleable solids, B.O.D., etc., shall be set up by state or local agencies and an industry required to pay for all in excess of that or,
2. With a maximum demand set up for the above constituents, whether an industry can build its own treatment plant and reduce its wastes to the maximum allowable in the city standard and thus avoid payment of additional charges to the city for handling its wastes in the public sewers and treatment plant.

"M. Consideration of charges to an industry that receives no other benefits from a city but pays large taxes. In some cases the taxes paid by an industry (*i.e.*, oil field wastes) might well be more than any charge that might be made for handling those wastes in a city plant. This would result in the city treating the wastes free if all taxes paid were rebated against the handling charge.

"N. Consideration that industries which have mutually neutralizing wastes join together in joint districts to consolidate their several wastes and turn out an effluent within the maximum limit set, thus avoiding any charges.

"O. Extent of requirement for pretreatment of any or all wastes before discharge into a public system.

"P. Devising of a basic formula taking into account the various elements which can be used by any particular municipality in adjudging the charges to be made according to the polluting or disturbing elements contributed by any of its industries.

"Q. Recommendations for an enabling act by state legislature to permit any particular city, county, or other local governmental agency, to set up regulations and devise formulae for charging for industrial waste treatment.

"R. Recommendations that study of industrial wastes and basis of handling by city, county, or other local governmental agency, be made by engineers engaged in and familiar with this phase of engineering.

"S. Recommendations that conferences be held between municipal officials, industrial plant management and engineers to arrive at a logical and satisfactory basis of charges."

The California Report suggests definite controls and contracts in connection with industrial waste treatment by municipalities, as follows:

"In order to have any control over industrial waste discharged into a public sewer, an application for permit should be required from all industrial users or prospective users of the sewage disposal facilities, showing the chemical composition and other characteristics of its wastes. Such application should include the following items:

1. Volume. Normal uniform flow, peak flow, and facilities for retention of flow to level off peak loads.
2. Suspended or settleable solids.
3. B.O.D.
4. Chlorine demand.
5. Temperature.
6. pH.
7. Oil.
8. Grease.
9. Sulfides.
10. Maximum size of solid particles.
11. Chemical contents (constituents which might affect the sewer lines or treatment plant through action on concrete or steel, inhibition of bacterial processes, etc.).
12. Odors or other nuisances.
13. New facilities required.

"A definite contract should be entered into between the governmental agency and the industry based upon one of the following policies:

1. Handle all wastes without charge. This may amount to an actual subsidy of the industry by the community.
2. Charge the industry according to the unit cost of handling the waste, based on cost per million gallons, pounds of B.O.D. or dry weight of solids.
3. Charge the industry for the extra cost of treating the industrial waste, *i.e.*, the extra cost above that of treating the sewage of domestic quality.
4. Charge the industry for treating its industrial waste but take into account all taxes paid exclusive of industry. This can be computed according to the following formula suggested by the committee:

T = all taxes paid to city exclusive of industry.
t = taxes paid by industry.
S = cost of operating sewerage works before industry contributes, paid by T.
s = industry's share of sewage works operation cost, without industrial wastes added, paid by t.

$$s = Ts/T$$

M = cost of operating sewage works with industrial waste added.
K = extra cost assessed to industry.

Then $K = M - (S + s) = M - S\,(1 + t/T)$."

Belleville, Ill.

In developing sewer rental charges for Belleville, Ill., George S. Russell, Cons. Engr. of St. Louis, wrote as follows:[6]

"In the past, for other communities, sewerage rate ordinances have been based on one of three methods.

"The first method is to base the service charges, or sewer rentals, on volume alone. This has been accomplished by charging on the basis of the volume of water used where water is metered, or by employing a rate per fixture of different types which could be proportioned on water use.

"The second method which has been used, bases the charge on strength alone. One basis for accomplishing this has been what is known as the "equivalent population" method. This method is usually predicated on the number of pounds of B.O.D. discharged to the sewer converted to equivalent population. In this computation the figure usually employed as representing the waste from one person is 0.17 lbs. of B.O.D. per day.

"The third method represents a consolidation of the first two, basing the rental charge on a combination of volume and strength of sewage. The City of Akron has recently adopted such an ordinance. It seemed to the officials of Belleville that such a method was the logical one, and the engineers were instructed to develop such a rate structure, comparing the results obtained by this method, with payments to be made under other methods.

"The cost of the improvements to be made at Belleville will be approximately $1,200,000. Of this amount, 60% can be charged to provisions to handle volumetric flow, and 40% as being chargeable to strength of the sewage, or B.O.D.

"If the B.O.D. of *all* sewage, domestic and industrial, were approximately the same then the volumetric method could be used without any inconsistency. As the average B.O.D. of domestic sewage in Belleville was close to 200 ppm., it was decided to establish rates on the basis of the water used alone, as long as the B.O.D. of the sewage averaged not more than 200 ppm., and to make an additional charge for wastes which have a B.O.D. greater than 200 ppm.

Using the figure of average domestic sewage strength at 200 ppm., and per cent of plant cost dependent on B.O.D. as 40%, it is apparent that the *additional* charge for B.O.D. in excess of 200 ppm., should be 40/200% or 1/5 of one per cent. It was also determined that in order to take care of operation and maintenance, and provide net earnings greater than 150% of that required for debt service, the sewer rental charge must be predicated on 60% of the existing water rates.

The "Belleville Formula" therefore becomes:

$$R = R_B + [0.002 \times (B.O.D. - 200)]R_B$$

Where
R = Rate per 100 cu. ft.
R_B = Basic rate per 100 cu. ft.
B.O.D. = ppm. B.O.D. of waste

"These determinations produced the following proposed rate structure:

Monthly Rates

	Cu. Ft.	Rate Per 100 Cu. Ft.
First	13,000	$ 0.20
Next	13,000	0.15
Next	27,000	0.125
Next	27,000	0.096
Next	54,500	0.072
All Over	134,000	0.066

Additional charge—for every part per million of biochemical oxygen demand that the industrial waste exceeds 200, add one-fifth (1/5) of one per cent."

In order to "sell" this program to the several industries, Mr. Russell reduced these sewage handling costs to costs per unit of industrial production. This gave each industry tangible figures which it could use in revising its cost of production. For example, the costs were calculated as follows:

Beer—7.2 cents per bbl.
Packing House—16.0 cents per hog.
Laundry—21.0 cents per 100 lb.
Catsup—0.33 cents per case.
Spaghetti—1.2 cents per case.

Allegheny County Formula

Another approach to a formula for charging industry was developed by Laboon, et al[7] as set forth below.

"The recommended schedule of rates follows:

The first 100,000 gal. per quarter @ 18c per 1,000 gal.

The next 1,000,000 gal. per quarter @ 12c per 1,000 gal.

The next 2,250,000 gal. per quarter @ 09c per 1,000 gal.

For all over 3,350,000 gal. per quarter @ 07c per 1,000 gal.

"It is provided however, that no bill would be rendered for less than 50c per month. No discounts would be allowed at the start. Flat rate charges shall be equivalent to 85% of the present flat rate charge for water usage now in effect in the City of Pittsburgh.

"Under the basic rate schedule as designed and offered herein, 17% of all domestic customers would pay 50c per month; 26% would pay between 50c and 75c per month; 22% would pay between 75c and $1.00 per month; 33% would pay between $1.00 and $2.00 per month and 2% would pay more than $2.00 per month.

"A special study has been made of the additional cost of treating excessive volumes of industrial wastes as measured in terms of total suspended solids, biochemical oxygen demand and chlorine demand in excess of normal requirements, based on primary treatment. An extra charge will be made to commercial and industrial establishments when the suspended solids are greater than 275 parts per million and the biochemical oxygen demand greater than 300 parts per million. The proposed formula on which the excess charge will be based is as follows:

$$F = 1 + R\left[\frac{0.75(S_1 - S_a)}{S_a} + \frac{0.25(B_1 - B_a)}{B_a}\right]$$

Where,

F = Factor to be applied to basic rate.

R = Ratio of Quality Cost to Total Annual Cost = 0.15.

S_1 = Suspended Solids of Sewage from particular industry in ppm.

S_a = Average Suspended Solids of all sewage = 275 ppm.

B_1 = B.O.D. of sewage from particular industry in ppm.

B_a = Average B.O.D. of all sewage = 300 ppm.

"The increase in cost on this basis is predicated on the actual treatment costs of the excessive volumes, suspended solids and biochemical oxygen demand. The charge is nominal. As an example, on the basis of a suspended solids content of 500 parts per million and a biochemical oxygen demand of 500 parts per million, the additional charge would be 11.7% of the total bill.

"An additional charge will also be made for treatment of wastes possessing an excessive chlorine demand. Chlorination of the effluent of the sewage treatment plant will be a requirement of the Sanitary Water Board. The chlorine demand of the central plant sewage cannot be determined until the plant is in operation and therefore only the rate formula can be given now, as follows:

$$R_c = FP_c(C_1 - C_a)$$

Where,

R_c = Surcharge Rate for Chlorine Demand in cents per thousand gallons.

C_1 = Chlorine Demand of wastes from particular industry in ppm.

C_a = Average Chlorine Demand of all sewage in ppm.

F = Factor for converting ppm. to pounds per thousand gallons = .00835.

P_c = Contract price of chlorine in cents per pound.

This charge likewise is nominal."

In reviewing this subject, one may well conclude with Mr. Murdock's statement that "there appears to be ample justification for combining the disposal of industrial residues with municipal sewage in a common processing plant. The total cost should be lower in such unified operation. When industries have to pay service charges, they will be more inclined to use every means available to reduce the over-all load on processing plants."

Among many others, Dr. Abel Wolman, Prof. of San. Engr., Johns Hopkins University, the writer, and Morris Cohn, Editor, *Sewage Works Engineering*, have all enunciated the principle that industry must bear its fair share of the cost of sewage treatment when its wastes are discharged to the city sewers and that such costs must be considered a legitimate cost of production.

The above formulas and ideas are presented here in hopes that they may serve as a basis for discussion among industry and municipalities faced with this problem. Its solution is not impossible and can be made quite equitable.

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UNDER YOUR GLASS TABLE TOP

By W. D. HATFIELD,
Superintendent
SAN. DIST. OF DECATUR, ILL.

In the operation of a water purification or sewage treatment plant the superintendent often finds it necessary to spend considerable time in calculating and arranging pertinent operating data, segregating costs, and planning repairs or rearrangements. Too often this takes more time than he has available. One means of reducing the time spent in these pursuits is to have a well organized office containing the proper reference books, hand books, magazines, and a file of blueprints and other necessary plant data.

Another method of reducing time spent on calculations is to keep certain data, formulas, curves, etc., available on sight. This saves a lot of time lost in looking for these items in reference books or in the plans of the plant. The best place to keep such information handy and always in sight is to put them under a glass top on your desk or work table. This is a convenient and time saving device.

The editors of *Water & Sewage Works* have asked me to write this short item listing what I have "Under My Glass Table Top." What I keep there may not be of interest or application to your plant but it may suggest other material that would be pertinent to your plant.

Cost Accounting Key

In Decatur, for example, in okaying bills for payment, it is my custom to follow the initials with two numbers—the first indicating the appropriation number to which the bill is to be charged, and the second to indicate the proper cost account. Therefore, I keep a list of appropriation and account numbers under the glass table top.

Plant Elevation Data

Another very useful set of information is a list of the elevations of structure, weirs, drains, basement floors, pump suction and discharge and flow levels. Having these data at your finger tips quite often saves a trip to the blueprint files. So helpful is this information, that this same list is posted on the bulletin boards about the plant for convenient use by the foreman and operators. (A flow diagram and profile plot would serve the same purpose.)

Plant Unit Capacities and Gas Measurements

Reference is occasionally necessary to certain plant unit capacities which are hard to keep in mind unless used every day. Therefore, under my table top is a list of cu. ft. or mgd. capacities of settling tanks, digestion tanks, filter beds, activated sludge aeration and settling tanks, pump and meter deliveries.

Our gas production is measured by orifice meters, which, by the way, have numerous advantages over the positive displacement meters so generally used. When gas production gets out of hand, it is easy to change to a large orifice. Under the table top is a list of flow constants for the different orifices we have in stock.

Flow Measurements and Formulas

Flow measurements about the plant are often conveniently made in conduits over weirs, with end contractions or without end contractions. So I keep handy three or four short tabulations of head and flow over such weirs which we frequently use.

Also under the glass are conversion tables of metric to English measurements, power equivalents, geometric equivalents, electrical units, conversion table for Centigrade to Fahrenheit temperatures, a table of proofreader's marks, and a list of atomic weights. In addition, there are conveniently listed formulas for computing detention periods, suspended solids, and B.O.D. loading.

There are many other items, data, and formulas that might be "under your glass table top" such as nomograms for certain calculations, formulas for calculating per cent sludge digestion for volatile matter content, or in water plants, dosage tables for chemical feeder settings, etc. There is, of course, a limit to the size of the table top and the things you personally want under it.

Comments of the Editors

"Kathy" Fiscus

To the memory of little 3-year-old "Kathy" Fiscus of San Marino, California, do we dedicate this special issue.

The daughter of David H. Fiscus, Distr. Mgr., California Water and Telephone Co., and Alice Fiscus, she plunged to her untimely death in an old abandoned water well April 8, 1949, and was removed from her 14 inch tubular prison 97 feet beneath ground some 52 hours later, Palm Sunday, April 10, 1949. If her tragic death hastens legislation prohibiting abandonment of such wells without filling or permanent sealing, she will not have died in vain.

Two Studies in Public Relations

Aside from those picayune "nuisance charges" collected by water utilities from customers for minor services, there is nothing which rubs the customer the wrong way so much as the too prevalent belief that the water utility is in cahoots with the local plumbing fraternity. This belief comes about as the result of advice from the water department or water company to the customer that he must have his leaking or half-choked service line repaired or replaced; that the water utility repairs and replaces service lines only up to the customer's property line; and, that the customer must have the work done on his property by an "approved" plumber. How many times have you, Mr. Supt., heard it said that the Water Dept. works in cahoots with the plumbers? Doesn't sound like very good Public Relations, does it?

Then, there is another problem in connection with customers' service lines. We refer to the matter of leakage from such lines which takes place between the property line and the customer's meter, and have often wondered to what extent the always embarrassing "unaccounted-for-water" and operating costs might be reduced if all leakage on customer's service lines be eliminated between the main and the meter. This is the hidden leakage (and not always hidden) which metering does not disclose or account for unless the meter is located at the curb. Therefore, it is leakage in which the customer takes minor if any concern as long as it does not damage his property. It is no less than human, then, that he resents the demand that he go into his pocket to pay the high costs of hiring "approved" plumbers and pay present day gray-market prices for materials to correct a condition which is costing him nothing, and perchance may actually be benefiting his shrubbery or flower beds.

During every severe winter there is the problem of frozen service lines, which not only imposes a heavy burden on the water utility but also results in arguments concerning responsibility—the water utility or the customer—when it comes to charging for service thawing. The question of where the freeze-up is located and who stands the thawing cost is practically always determined by the water utility. Nine times out of ten the customer pays.

In an endeavor to eliminate these two important customer relationship problems the municipally-operated Water and Light Utilities of Kalamazoo, Mich., has done the unusual in assuming the repair, maintenance and replacement of *all* water service lines from main to meter, *no matter where the meter is located.* In his article in this issue which tells of this uncommon (considered heterodox by some) policy and practice of a water utility, Manager Earl E. Norman, after fourteen years of experience with the practice, pointedly says—"After all, no one should be more interested in assurance of customer service lines of proper size and materials, maintained in good condition, than the water utility itself". He also emphasizes that this is not to be considered in any sense a free service, since the customer pays the full charge of initial installation at approximate cost; and, that the continuing maintenance cost averaging 75 cents per customer per year is covered in the rate schedule. Considering the results this cost appears insignificant.

When we questioned Mr. Norman on his experiences with this unusual policy of service-line installation and maintenance, we had heard of no parallel case. More recently, however, we have learned of a similar policy and practice which has been in effect in Reading, Mass., for a number of years. In a letter from Philip Welch, Supt. of Public Works at Reading, we learn that some time ago the Board of Public Works approved his recommendation to eliminate the many existing "nuisance charges" to customers. Amongst these were the charges for service thawings and making repairs to service lines on the customer's property, for whatever reason.

The Public Works Dept. of Reading for some years, now, has maintained all service lines *from main to the customer's meter,* and replaces such lines when the necessity arises, at no cost to the customer. The only exception to this rule is when the customer requests replacement of an existing service, considered adequate in size by the Department, with a larger pipe size for some new service. In addition, a charge is made for repair or replacement of service where the service pipe has been damaged as the result of some act of the customer. Damage resulting from the grounding of electrical circuits on the water service line constitutes one such damage.

Mr. Welch states that, beyond those charges cited above, *all* other service charges and service line maintenance and replacement have been abolished and such costs are covered in the rates for water service. "Happily," states Mr. Welch, "we have experienced a marked drop in complaints, and our contacts with the public have come to be much more pleasant."

These represent the only two cases of the same extent which have come to our attention. If our readers can report others of similar nature we would like to have the information. Considering these two cases as possible forerunners of what may come, it occurs to us that more than likely water utilities will some day be required to assume full responsibility for maintenance, if not also installation of service lines up to the customer's meter, wherever the meter may be located. When considered in the light of practices of the closely akin gas and electric utilities, the question which is highly likely to be put to water utilities from now on is this—"If it is common (required) practice for the gas and electric utilities to install and maintain service lines up to the customer's meter, then why should not the water utility do likewise?"

If the experiences of Kalamazoo and Reading can be cited as examples, there should result a more satisfactory water service, more satisfied customers and advanced public relations.

L. H. Enslow

YOU NEED BOTH HALVES OF THE SCISSOR

In the CHICAGO Comminutor the cutters and shear bars cut and chop; the channel feeds and holds.

The combination of channel and rotating drum makes the CHICAGO Comminutor the only effective method for cutting and screening sewage solids in the stream.

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Over 2000 successful installations prove "You Need Both Halves Of The Scissor."

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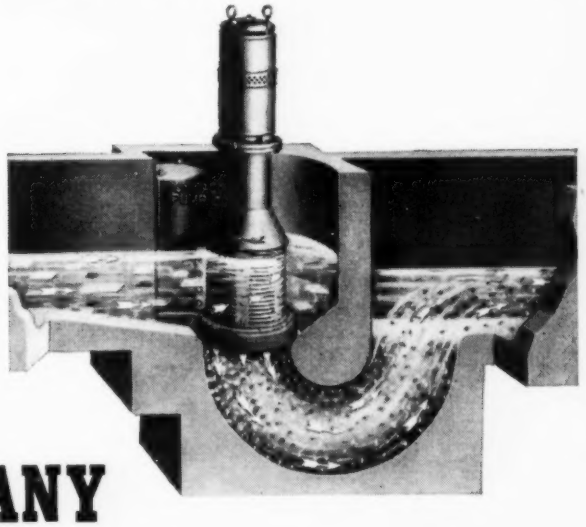

Cross section of a CHICAGO Comminutor channel illustrates a typical design of controlled discharge channel. Sheared small particles must pass through a maximum drum slot width of 3/8 in. Comminuted matter completely settles out in the primary tanks.

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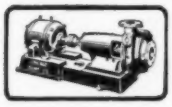
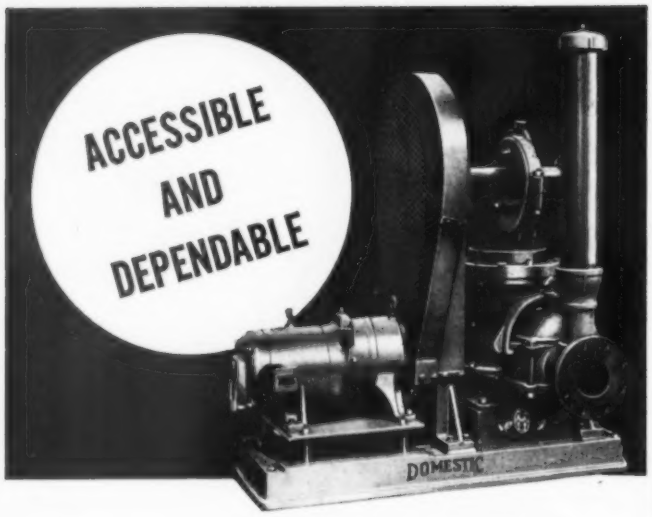


Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.



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DOMESTIC plunger sludge pumps are today performing herculean tasks in every state in the Union, many after decades of gruelling use.

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Capacities from 35 G. P. M. to 375 G. P. M. at heads up to 115 feet.

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ENGINE & PUMP COMPANY
A DIVISION OF EMPIRE INDUSTRIES, INC.
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MEETINGS SCHEDULED

MAY 11—BELLINGHAM, WASH. (Bellingham Hotel)
Pacific Northwest Sewage Works Assn. Sec'y-Treas., Wm. P. Hughes, City Engineer's Office, City Hall, Lewiston, Idaho.

MAY 12-14—BELLINGHAM, WASH. (Bellingham Hotel)
Pacific-Northwest Section A.W.W.A. Sec'y-Treas., Prof. Fred Merryfield, Oregon State College, Corvallis, Ore.

MAY 19—WARE, MASS. (The Quabbin Reservoir)
New England Water Works Assn. Sec'y, Jos. C. Knox, 204 Tremont Bldg., Boston, Mass.

MAY 19-21—STOCKTON, CALIF. (Hotel Stockton)
California Sewage Works Association. Sec'y-Treas., L. H. Cook, P.O. Box 696, Menlo Park, Calif.

MAY 23-25—TRAVERSE CITY, MICH. (Park Place Hotel)
Michigan Sewage Works Association. Sec'y-Treas., D. M. Pierce, Dept. of Health, Room 334, Administration Bldg., Lansing, Mich.

MAY 25—BRISTOL, CONN. (Bristol Country Club)
New England Sewage Works Association. Sec'y, Walter E. Merrill, State Dept. of Health, State House, Boston, Mass.

MAY 30-JUNE 3, 1949—CHICAGO, ILL. (Stevens Hotel)
American Water Works Association Annual Conference. Exec.-Sec'y, Harry E. Jordan, 500 Fifth Avenue, New York 18, N.Y. (All reservations will be cleared through the A.W.W.A. office.)

JUNE 5-11—GAINESVILLE, FLA. (University of Florida)
Florida Short Course & Conference for Water & Sewage Plant Operators. Chairman, David B. Lee, Bureau of San. Eng., State Board of Health, Jacksonville, Fla.

JUNE 6-7—KINGSTON, N.Y. (Governor Clinton Hotel)
New York State Sewage Works Association. (Spring Meeting). Sec'y, Ralph C. Sweeney, State Dept. of Health, 19 E. Main St., Rochester 4, N.Y.

JUNE 9-11—TUSCALOOSA, ALA. (University of Alabama)
Alabama Water & Sewage Association & Short School. Sec'y-Treas., Prof. G. H. Dunstan, Univ. of Alabama, Tuscaloosa, Ala.

JUNE 15—WOODLAND, ME.
Maine Water Utilities Association. Sec'y, Earle A. Tarr, Winthrop, Me.

JUNE 17-18—CHICAGO, ILL. (Hotel Sherman)
Central States Sewage Works Association. Sec'y-Treas., Paul W. Reed, 1098 W. Michigan St., Indianapolis, Ind.

JUNE 22-24—CLEVELAND, OHIO (Carter Hotel)
Ohio Sewage & Industrial Wastes Treatment Conference. Sec'y-Treas., G. A. Hall, 302 Dept. of State Bldg., Columbus, Ohio.

JUNE 23—WANAQUE, N. J.
New Jersey Section A.W.W.A. (Outing and Inspection) Sec'y, C. B. Tygert, P. O. Box 178, Newark, N.J.

JUNE 29—PORTSMOUTH, N.H. (Hotel Wentworth-by-the-Sea)
New England Water Works Assn. Sec'y, Jos. C. KNOX, 204 Tremont Bldg., Boston, Mass.

JUNE 29-JULY 1—BATON ROUGE, LA. (La. State University)
12th Annual Louisiana Water & Sewage Short Course. Director, John H. O'Neill, Dept. of Health, Civil Courts Bldg., New Orleans, La.

MEETINGS SCHEDULED

AUG. 10—RANGELEY, ME.
Maine Water Utilities Assn. Sec'y, Earle A. Tarr, Winthrop, Me.

AUG. 22-24—STATE COLLEGE, PENNA. (Nittany Lion Inn)
Pennsylvania Water Works Operators' Association. Sec'y, I. M. Glace, 1001 North Front Street, Harrisburg, Pa.

AUG. 24-26—STATE COLLEGE, PENNA. (Nittany Lion Inn)
Pennsylvania Sewage & Industrial Wastes Association. Sec'y-Treas., Bernard S. Bush, Kirby Health Center, Wilkes-Barre, Pa.

SEPT. 8-9—MINNEAPOLIS, MINN. (Nicollet Hotel)
Minnesota Section A.W.W.A. Sec'y, R. M. Finch, 518 Metropolitan Life Bldg., Minneapolis, Minn.

SEPT. 13-16—DIXVILLE NOTCH, N.H. (The Balsams)
New England Water Works Association. Sec'y, Joseph C. Knox, 204 Tremont Bldg., Boston 8, Mass.

SEPT. 20-22—DES MOINES, IOWA (Hotel Kirkwood)
Iowa Sewage Works Association. Sec'y-Treas., Leo Holtkamp, P.O. Box 310, Webster City, Iowa.

SEPT. 21-23—ATLANTA, GA. (Georgia Institute of Technology)
Georgia Water & Sewage School. Sec'y-Treas., Van P. Enloe, R.F.D. No. 5, Box 363, Atlanta, Ga.

SEPT. 21-23—WHEELING, W. VA. (Oglesby Park)
W. Virginia Industrial Wastes & Sewage Works Assn. Sec'y-Treas., R. G. McCall, Dept. of Health, Room 643, State Capitol, Charleston 5, W. Va.

SEPT. 26-28—SCHUMACHER, ONTARIO (McIntyre Arena)
The Canadian Institute on Sewage & Sanitation. Sec'y-Treas., Dr. A. E. Berry, Ontario Dept. of Health, Parliament Bldgs., Toronto, Ont.

OCT. 12—OLD TOWNE, ME.
Maine Water Utilities Assn. Sec'y, Earle A. Tarr, Winthrop, Me.

OCT. 17-19—PITTSBURGH, PA. (Hotel Wm. Penn)
Engineers' Society of Western Penna. Chairman, H. M. Olson, Wm. Penn Hotel, Pittsburgh, Pa.

OCT. 17-20—BOSTON, MASS. (Statler Hotel)
Federation of Sewage Works Associations. Executive Secretary, W. H. Wisely, 325 Illinois Bldg., Champaign, Ill.

OCT. 19-21—JACKSON, MISS. (Heidelberg Hotel)
Alabama-Mississippi Section A.W.W.A. Sec'y-Treas., J. L. Snow, 601 First National Bank Bldg., Montgomery, Ala.

NOV. 2-4—WASHINGTON, D.C. (Wardman Park Hotel)
Chesapeake Section A.W.W.A. (1st Annual Convention) Sec'y-Treas., C. J. Lauter, 5902 Dalecarlia Place, Washington, D.C.

NOV. 17—BOSTON, MASS. (Hotel Statler)
New England Water Works Assn. Sec'y, Jos. C. Knox, 204 Tremont Bldg., Boston 8, Mass. (Next meeting Dec. 15th.)

DEC. 5-7—AUGUSTA, GA.
Southeastern Section A.W.W.A. Sec'y, T. A. Kolb, Room 433 Wade Hampton Office Bldg., Columbia, S.C.

DEC. 14—AUGUSTA, ME.
Maine Water Utilities Assn. Sec'y, Earle A. Tarr, Winthrop, Me.

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With the largest and most completely equipped organization in the well water developing field, Layne has always provided excellent service for even the smallest plants. In no case have they had to pay a penalty for Layne's world-wide experience and outstanding success. As a matter of fact, Layne Well Water Systems actually cost less when the advantages of unquestionable high quality, proven efficiency and extra long life are considered.

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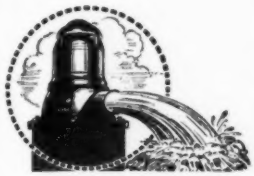

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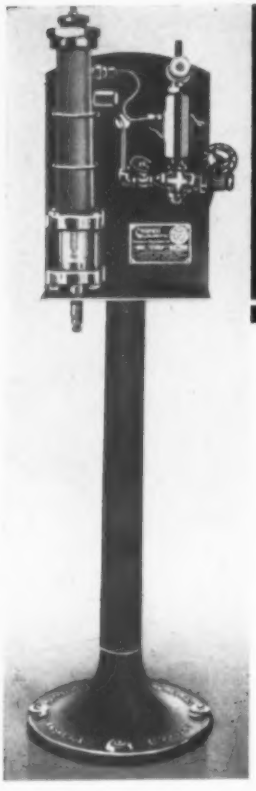
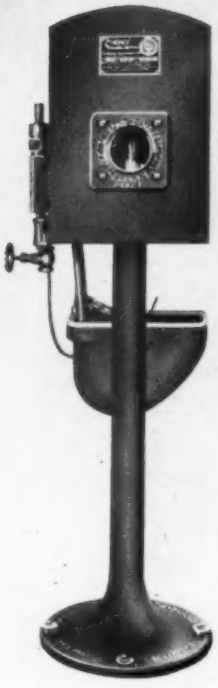


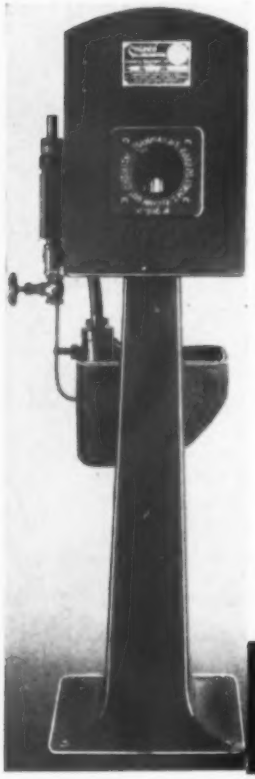
CHEMCO Type M-5
CHLORINATOR
CAPACITY RANGES
0-10 lbs. per 24 hours

Chemco CHLORINATORS



Chemco Chlorinators are the result of nearly 25 years experience in water treatment and are used in 42 of the 48 states and foreign countries.. They have outstanding design features as shown below...

CHEMCO Type M-3
CHLORINATOR
CAPACITY RANGES
0-10, 0-15, 0-25
lbs. per 24 hours



CHEMCO Type M-1
CHLORINATOR
CAPACITY RANGES
0-10, 0-25, 0-50
0-100, 0-200, 0-300
lbs. per 24 hours

1 CHEMCO Chlorinators are simple, sturdy and foolproof in design.

2 CHEMCO Chlorinators are all based on vacuum design

3 CHEMCO Chlorinators can be flooded with water without damage.

4 CHEMCO Chlorinators have no regulator plates, springs or diaphragms to eat out and cause expensive repair cost.

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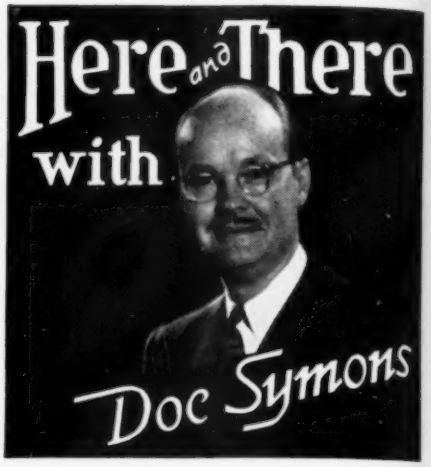


H.T.M.A.—And need I remind you what issue this is, or that you should retain your '48, '47, '46 *and* '45 in order to have a complete Ref. and Data file. Of course, you know that the index in this issue covers all of these back issues, too.

* * *

And now to the month's business, of which the most important is the A.W.W.A. meeting, beginning on the 30th—or the 29th if you want in on the Sunday fun. Inasmuch as I'm writing this from Chicago, and you'll be here soon, let me take you on a fast tour.

You'll be staying at the Stevens, the world's largest hotel, and one with good food. There are a couple of good bars in the neighborhood, say the Glass Hat, at the Congress, etc., but for me the near north side is a little more familiar.

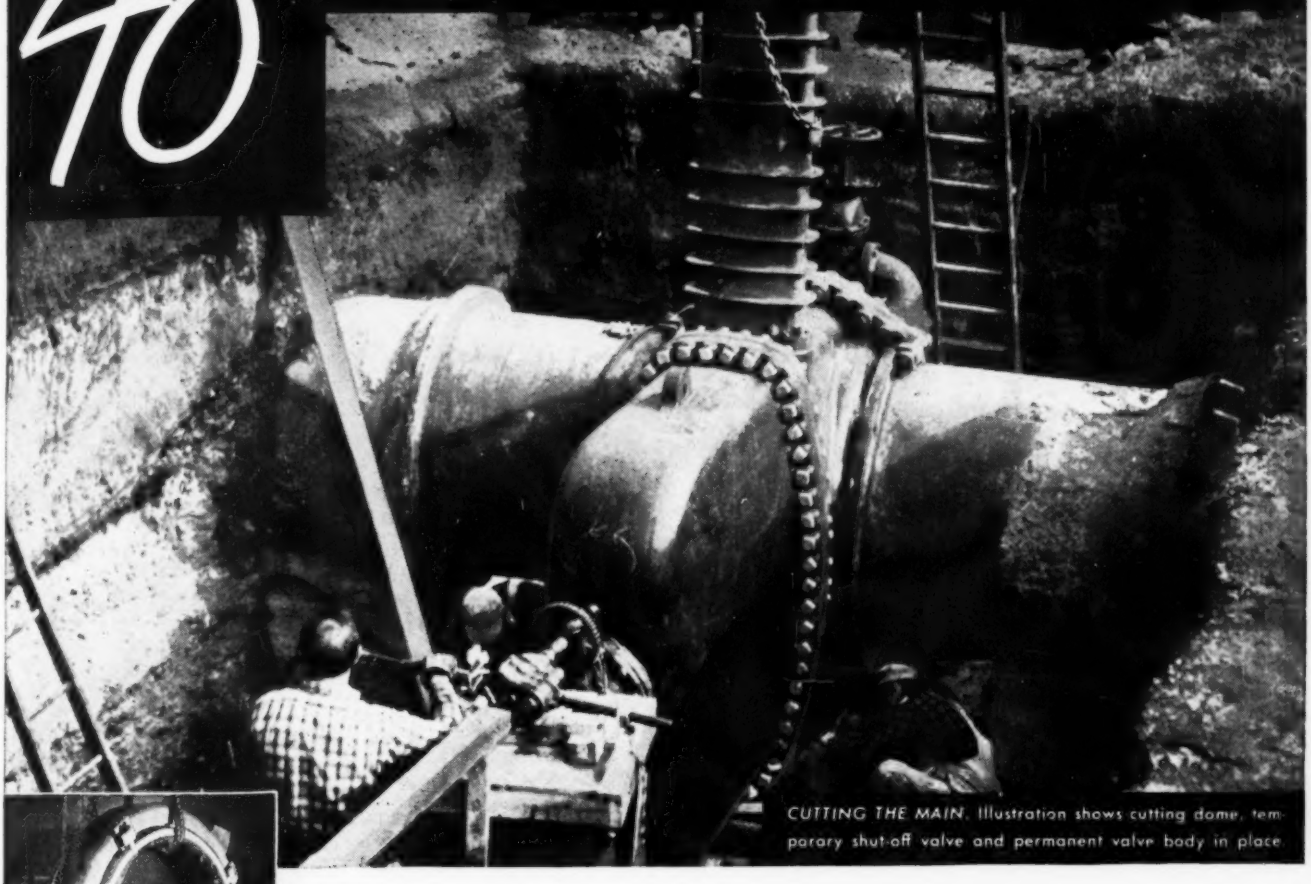
At Chicago Ave. and Michigan stands the Old Water Tower, which also graces the front cover of this number. A few blocks to the north is the Palmolive Building, atop which a 200,000,000 candle power beacon knifes its way through a black sky. West of the Water Tower, a short block, is Rush Street, which for some unknown reason veers from north to northwest. Maybe it was bent by the heavy weight of restaurants and bars which nightly turn its last five blocks into gaudy daylight.

In addition to three sandwich shops and a drug counter, there are just two dozen places where you can find a meal, refreshments, and in many cases, entertainment, and of the whole lot, including sandwich shops, all but six are on the same side of the street. You may take your pick—from The Tradewinds, The Pit, and The Prow, to the Casba, Singapore, and the Dipsy Doodle, with a Bit-O-Sweden or Italian food if you prefer.

Just where Rush Street disappears into State is Agostino's, my favorite, and if you like spaghetti and want to

*48" GATE VALVE INSERTED UNDER PRESSURE

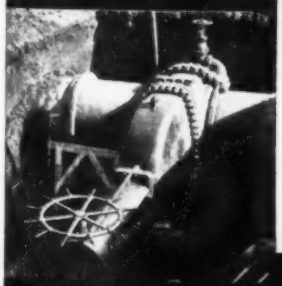
to Avoid Stoppage of Steel Production



CUTTING THE MAIN. Illustration shows cutting dome, temporary shut-off valve and permanent valve body in place

Section removed from main

Finished insertion



At a large Eastern steel mill uninterrupted production depended upon a thirty year old, 48" cast iron main, carrying sea water used for cooling the furnace jackets. The main was in poor condition — badly corroded and electrolytically pitted.

In order to provide an emergency by-pass in the event of line failure, a gate valve was required. Since the mill could not risk even a momentary shut down, Smith was asked to insert the valve under pressure. Although of unprecedented size, the insertion was completed in four days without interruption of service or reduction in pressure.

*First 48" insertion ever made under pressure. One month later a second 48" gate valve was inserted by Smith for the Water Bureau, Philadelphia, Pa.

29

GATE VALVES
CHECK VALVES
FIRE HYDRANTS
INSERTING VALVES
TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.
ESTABLISHED 1896
EAST ORANGE, NEW JERSEY

FLOOR STANDS
INDICATOR POSTS
TAPPING MACHINES
INSERTING MACHINES
PIPE CUTTING MACHINES
CORPORATION TAPPING MACHINES

eat it where the natives go, try Agostino's. It's not pretentious, it's upstairs, and the food is excellent. I hope you get Vito to serve you.

If it should be Smorgasbord deluxe which you desire, the Kungsholm, where the food is delicious, the decor delightful and the prices—well—but where the famous Marionette operas may not be available because of a recent fire. For delectable fried shrimp, with tantalizing sauces, go to Don the Beachcomber's where the atmosphere is as exotic as the unusual rum drinks. Or, if you just want a good shrimp cocktail for lunch, I recommend the Cape Cod Room, which opens at noon in the Drake Hotel, home also of the Coq d'Or and the beautiful Camellia House.

For French atmosphere, and if it is warm, eat in the patio of Le Petit Gourmet, where you will be surrounded by lovely antique shops. If you want to see the lights of Chicago at night, go up to the Tip Top Tap at the Allerton Hotel. It is not the "Top of the Mark," which you San Francisco visitors remember, but there are only two other places in Chicago with an equal view, and they are private clubs. (The view south is the best.)

Now if it's German food, there's the Golden Ox somewhat further north; and baked chicken or shiskebab are the specialties of Col. Yachenko at the exquisitely continental Yar Restaurant in the Lake Shore Hotel. And then there's the famous Pump Room of Ambassador East where the shaslik flames on the sword, and where you can easily spend $10 for lunch.

Back in the Loop, is the new Swiss Chalet at the Bismarck, serving wonderful wiener schnitzel, and a kind of onion pie, said to be delicious. For game, and other *good* food, try the Bohemia Cafe across from the Union Station—AND go to Carder's on Dearborn near Randolph for just good home cooking, especially a sizzling platter of liver and bacon with corn bread sticks.

Of course, if you don't want to stray too far from convention headquarters, there are several places to spend a delightful hour in the Stevens, including the Boulevard Room, and a short distance away is the Blackstone's Mayfair Room, still quite a place, and where you may see a few show folk. And, not too far away is the renowned Blackhawk Cafe, maker of name bands. But, if I know my convention go-ers, you won't have any trouble finding your own favorite spot.

* * *

A couple of years ago at Purdue—Purdue, that's where Professor (no less) Don E. Bloodgood puts on those wonderful Industrial Waste Conferences—to continue: A couple of years ago at Purdue the Central States Sewage Works Assn. was holding its meeting. I was attending for the express purpose of giving my talk on Public Relations and covering the meeting for *W. & S. W.*; neither of which has anything to do with the story, but I just wanted to get in a plug.

At the annual banquet one of the entertainment features was a continuation of the famous feud between the engineers and the chemists. As usual, C. C. "Swede" Larson, that D.P.B.* from Springfield, Ill., spoke for the chemists, and Don Bloodgood held forth for the engineers. The result of the banter was some impromptu entertaining by prominent representatives of both professions.

Dr. F. W. (Mohlie) Mohlman, Dir. of Labs, Chicago Sanitary District, played the "Water Survey Rag" which he had written while at the University of Illinois in 1916 as one of "Bartow's Boys." Dr. W. D. Hatfield (Hap to you), Supt. of Sewage Works, Decatur Sanitary Dist.,

*Dual Personality Boy.

CLEAN PIPE WITH "FLEXIBLE" TOOLS

PICK THE MOST SUITABLE TIME

SAVE MONEY TO BOOT!

"FLEXIBLE" tools have shown their practical value in over 15 years of pipe cleaning work. During that time, millions of feet of pipe have been cleaned, under all conditions. That's why, today, we offer this equipment confidently—for sale, lease, or contract. Designed by specialists—proven in the field—"Flexible" tools *will clean your lines in shorter time and at lower costs.* Proof is available. Ask for it.

DON'T DIG 'EM UP—clean 'em. It costs less! Rent the tools—buy 'em or contract the work. Fit the job to your budget, and invest the savings in other forward-looking projects.

STANDARD PRESSURE LINE SCRAPERS FROM 6" to 36"

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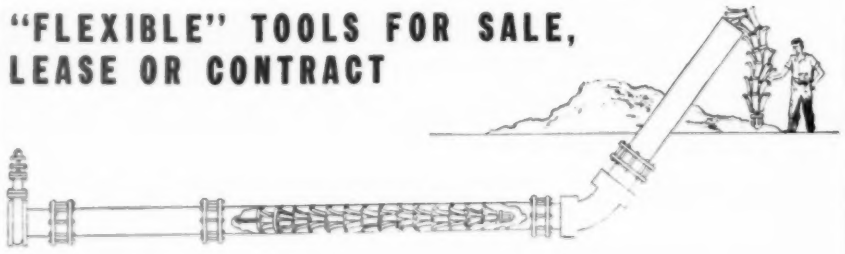

WRITE FOR ILLUSTRATED LITERATURE TODAY

REMEMBER, ECONOMY STARTS WHERE PROVEN METHODS ARE USED

FLEXIBLE UNDERGROUND PIPE CLEANING CO.

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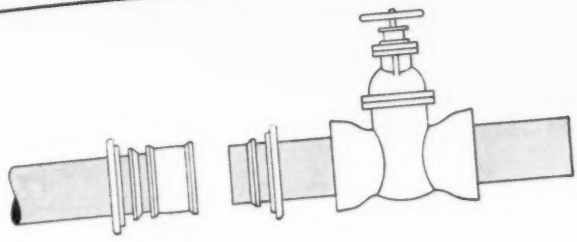
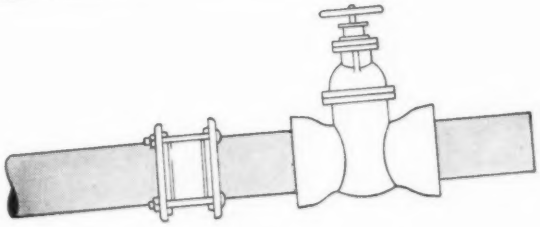
IDEAL WAY to extend a main

1



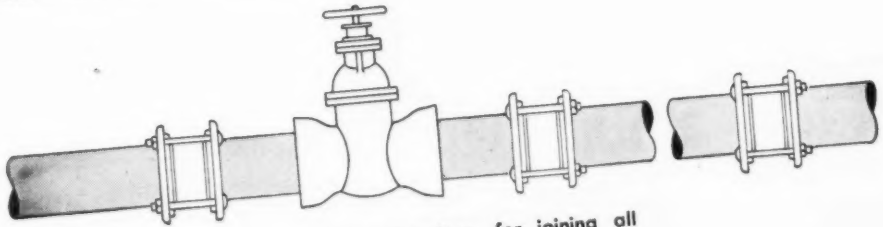
Insert plain-end nipples in each side of valve (in shop, to cut shutdown time). On end of existing main, place follower ring, gasket and middle ring of Dresser Coupling. Place other follower ring and gasket on nipple end of valve.

2



Position valve, slip coupling parts into place over pipe ends and tighten bolts of Dresser Coupling.

3



Use Dresser Couplings for joining all pipe lengths in your new main extension.

Why is this the ideal way to insert valves and run main extensions?

Because Dressers provide the simplest way to join pipe. The only tool needed is a wrench. Work progresses rapidly since there is no lead or compound to heat or pour. Joining with Dressers eliminates guesswork, too; any workman can make a permanent, absolutely bottle-tight connection every time. This method also permits the use of odd lengths of plain-end pipe you may have in stock.

Made to "live in the ground", Dresser Couplings absorb vibration, protect pipe, valves and fittings against harmful stresses, keep the line trouble-free.

Detailed, factual literature on how Dresser products can solve your water line coupling and repair problems is yours for the asking. Write today.

DRESSER "FLEXIBLE-TIGHT" **COUPLINGS**

Dresser Manufacturing Division, 59 Fisher Ave., Bradford, Pa. (One of the Dresser Industries), • In Texas: 1121 Rothwell St., Houston
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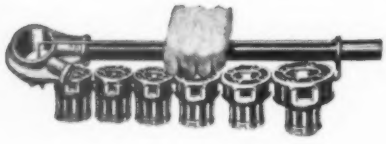
Now it's a Cinch

TO THREAD SMALL PIPE



Free handy carrier for any group of sizes.

RIDGID Ratchet Threaders No. 00R, 111R and 12R are extra handy for 1/8" to 2" pipe

● Light strong efficient RIDGID ratchets give you perfect threads on 1/8" to 2" pipe — fast, without bothersome get-ready. Precision cut tool-steel dies. Die heads snap into ratchet ring from either side, can't fall out. You don't need special dies for close-to-wall threads. No. 00R, 1/8" to 1" pipe; No. 111R, 1/8" to 1¼"; No. 12R, 1/8" to 2." Conduit dies furnished on request. Buy these handy work-savers at your Supply House.

RIDGID

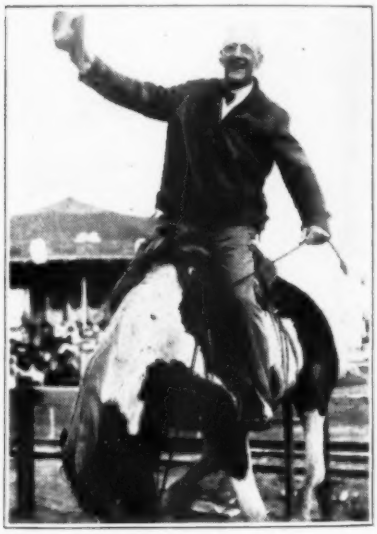
WORK-SAVER PIPE TOOLS

THE RIDGE TOOL CO. • ELYRIA, OHIO

played some Rachmaninoff on the piano; "Swede" of course gave forth on his violin. A quartet of Mu San boys representing the engineers sang their fraternity song, "The Garbage Man's Daughter," under the direction of Prof. Harold E. Babbitt, of the University of Illinois. And if you wonder how I got into that quartet, the story goes back to 1930 when I was an instructor and they sneaked me in.

* * *

Kokomo Bill Rides Again: Out Chicago way, in fact throughout the whole midwest, *and* much of the east, everyone knows Wm. T. (Bill) Birch, inventor and manufacturer of extraordinary pump valves, and extoller of the virtues of the steam pumping engine. Stricken with a heart attack about year ago, "Bill" has been recuperating in Phoenix, Arizona. As you can see from the picture here-

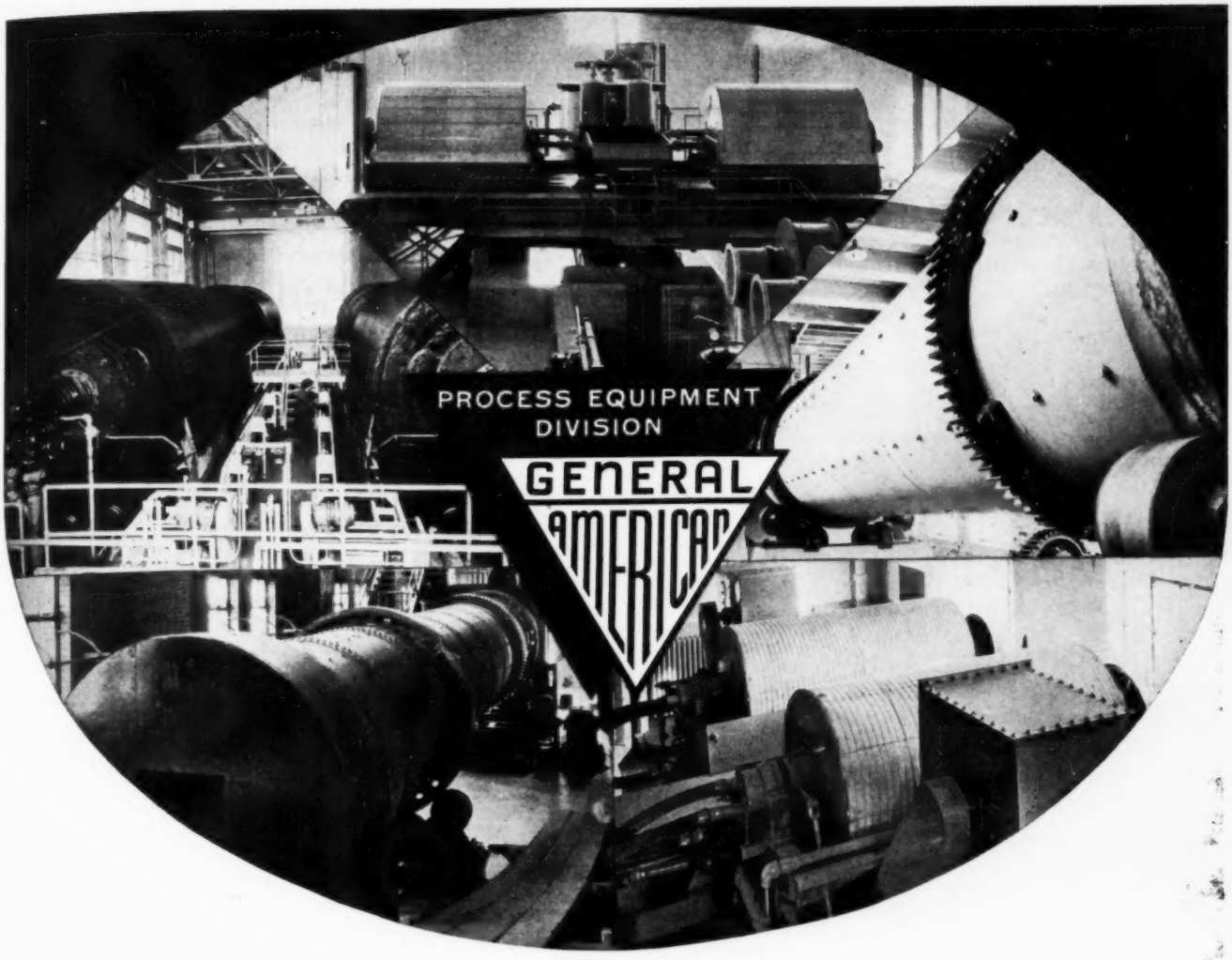


with, he's quite a cowboy now and is expecting to be back in Chicago for the A.W.W.A. convention. — He's Bill to everyone else, but my Dad always called him "Kokomo," for having both come from that Indiana city they were life-long cronies. Glad to see ya' ridin' again, "Kokomo!"

* * *

If you listen to the radio regularly —*and* if you are a devotee of The Great Gildersleeve, you undoubtedly heard the program on March 23, when A.W.W.A. past president Sam Morris (Gen. Mgr. of the Los Angeles Water and Power Dept.) presented "Gildy" with a complimentary membership in A.W.W.A.—It was not, as some one told me, an honorary membership, which is voted to outstanding water works men by the Board of Directors.

Also, if my spies are correct, the original presentation was made by



Modern Sewage Treatment Plants

require equipment that has proved itself efficient and is backed by individual responsibility for design, engineering, fabrication and initial operation.

General American Conkey Sludge Filters—the first to be used for large scale dewatering of sludges such as primary, elutriated-digested, Guggenheim Process, etc.—are dewatering more than a thousand tons of dry solids daily.

General American Louisville Dryers have been successfully used for years drying both activated and digested sludges. Type "L", with patented fire-conduits to eliminate scorching or burning, produces a uniformly high quality maximum yield of dried product for fertilizer or earth conditioner.

Let the experience and knowledge of General American engineers help you while your plans are in the blue print stage.

OTHER
GENERAL AMERICAN EQUIPMENT

SLUDGE DRYERS	*TURBO-MIXERS*	*THICKENERS*
SLUDGE GASHOLDERS	*STORAGE TANKS*	*SCREENING DEWATERERS*

GENERAL AMERICAN TRANSPORTATION CORPORATION

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Linn Enslow, current president of A.W.W.A., at the meeting of the California Section last fall. Here's the photograph to prove it.

In case you don't know—Reading from L. to R.—L. W. Grayson, Chairman, Calif. Section; Linn Enslow, Hal (The Great Gildersleeve) Peary, and Harry Jordan, Secy. A.W.W.A. "Gildy," as you know, is not only water commissioner of Summerfield on the radio; he is also Water Commissioner of Arcadia, Calif. at $1.00 a year.

And here's more to the story—On the day of the radio presentation, Art Clark, Secy.-Mgr. of W.S.W.M.A., wired Gildersleeve that the W.S.W.M.A. conferred on Gildy the title of "Honorary Water Works Peddler—with deepest sympathy."

* * *

And to return to more letters in my correspondence file. "Rollie" (Omega Machine) Leveque came through with a letter about Plato's opinion of salesmen (peddlers, to you). Rollie wrote as follows:

"Here is the excerpt from Plato's discussion on 'The Republic'. You may recall that until I read this, I had rather an exalted opinion of our profession. Mr. Plato, it would seem, held 'peddlers' in rather low esteem. No wonder kids would rather be motormen, firemen, and policemen instead of salesmen. Well, here's Plato's discourse"—

"—Then we shall want merchants?

—We shall

—And if the merchandise is to be carried over the sea, skillful sailors will also be needed, and in considerable numbers?

—Yes, in considerable numbers.

—Then, again, within the city, how will they exchange their productions? To secure such an exchange was, as you will remember, one of our principal objects when we formed them into a society and constituted a State.

—Clearly, they will buy and sell.

—Then they will need a market-place and a money-token for purposes of exchange.

—Certainly.

—Suppose now, that a husbandman, or an artisan, brings some production to market, and he comes at a time when there is no one to exchange with him, is he to leave his calling and sit idle in the market-place?

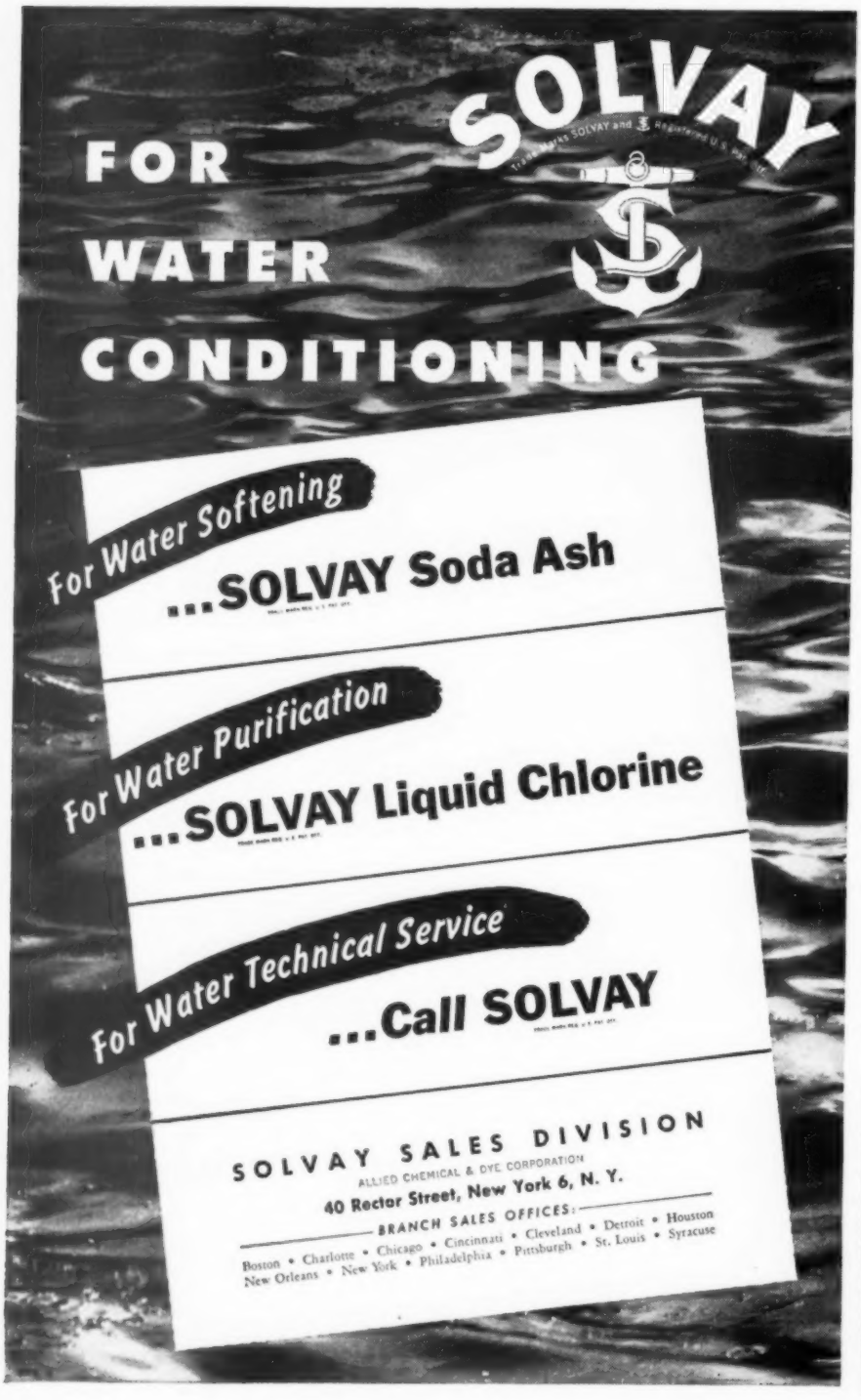
—Not at all; he will find people there who, seeing the want, undertake the office of salesmen. In well-ordered states, they are commonly those who are the weakest in bodily strength and therefore of little use for any other purpose; their duty is to be in the market, and to give money for goods to those who desire to sell and to take money from those who desire to buy."

"So you see, Doc, we poor peddlers have had two strikes on us for centuries. Guess I should go back to water-making. Incidentally, in case you are interested, 'Chemical Feeders' spelled backwards is 'Lacimehc Sredeef'."

* * *

At this year's meeting of A.W.W.A., you won't get your picture taken on a Board Walk, as did Mrs. Charlie (Roanoke, Va.) Moore last year at Atlantic City. Is this the picture you were looking for, Charlie?

Incidentally, I didn't take this picture—that's why it's so good.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ROTO-TROL

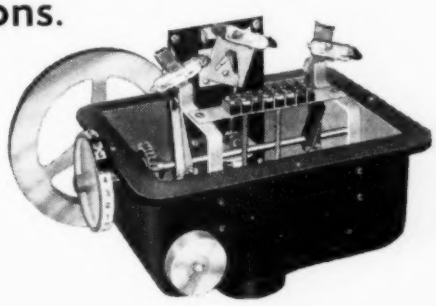
For long life, dependable service, flexibility and efficient operation of single or multi-pump installations.

ROTO-TROL 940

The 940 Roto-Trol will control your pumps, valves, alarm circuits, etc., all from one float. Each circuit is completely independent from all others and may have several starting and stopping positions on both a rising and falling level. This feature permits programming your pumps to operate them in about any combination to deliver the volume to your plant or system most consistent with your inflow. Differentials between on or off can be as small as 3 inches or as large as several feet.

This Roto-Trol can be set on the job, as no special tools or experience is required.

This control is furnished having two to ten or more circuits and all circuits are made through the snap action of mercury switches.

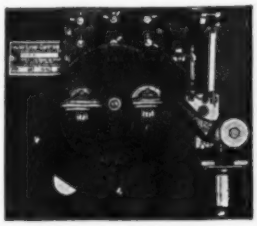


ROTO-TROL RF-2

The "RF-2" two-pump Roto-Trol with a built-in Alto-Trol combines in one cast iron cabinet all that is necessary to provide dependable operation of your two pumps from the movement of one float.

This control also will provide the automatic alternation of the two pumps, allowing them to operate either singly or together as the demand requires. Each pump circuit is completely independent of the other.

In most cases, this Roto-Trol will prove less expensive to install than two separate float controls plus a separate alternator, as there is but one float, and wiring need be done only from this one Roto-Trol to the motor starters. The "RF-2" can also be furnished for straight sequence control of from one to eight circuits.

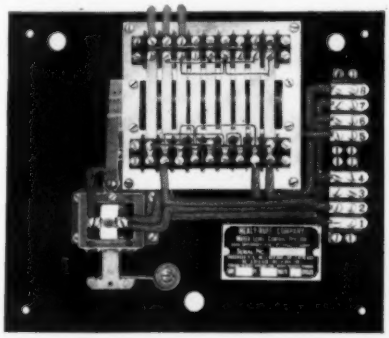


ROTO-TROL TYPE "A"

Controls the water line in your elevated tank, standpipe or reservoir from your pump house. You can do this by installing a Type "A" Roto-Trol. This Roto-Trol automatically compensates for sudden changes in pressure due to surges. The Type "A" Roto-Trol's time delay also provides backspin protection for your deep well pump when desired. This Roto-Trol is furnished in both single and multi-pump combinations.

OTHER DEVICES:

Single Pump Float Controls
Pressure Operated Sewage Controls
Remote Controllers
Float Operated Depth Indicators
Alarm Silencers
Special Controls Engineered to meet special requirements.



ALTO-TROL

The Alto-Trol is an electrically operated sequence changer used to alternate the cycle of operation of 2, 3, 4 or 5 pumps or similar pieces of equipment. It is used with any standard pilot control, such as any ROTO-TROL, or any pressure, float or vacuum switches. No extra circuit or set of contacts is required for its operation. Simple, trouble-free, dependable. Designed for use with 2, 3, 4, or 5 pumps, to equalize wear.

Write for Bulletins which give Complete Description and Engineering data.

Twenty Years of Specializing in Controls for Water and Sewage Works.

WATER LEVEL CONTROLS DIVISION

HEALY-RUFF COMPANY

783 HAMPDEN AVENUE — ST. PAUL 4, MINNESOTA

Had a letter from L. J. (Tiny) Hoffman, of the Akron, Ohio, water works, who told me a story about his "friendly, brown, felt hat." Seems "Tiny" once obtained one of those "hat protection cards" from Mr. Smith of Badger Meter Co.—You know those cards that you stick in your hat band, like this one—

Like Hell It's Yours . . . Put It Back!

This Belongs To

Phone

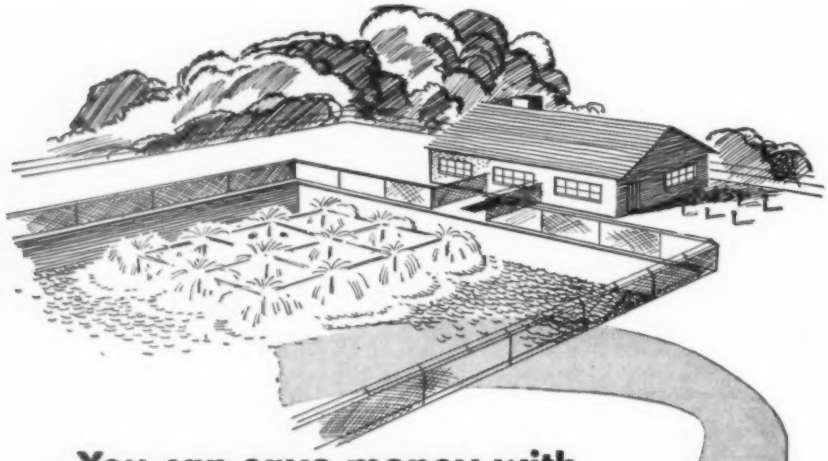
Seems also, that "Tiny" took this hat on a trip from Akron through Kentucky, Tennessee, and Georgia to Florida. Along about Griffin, Ga., "Tiny" took said hat with said hat protection card into a restaurant and hung it on a hook. It was a warm and sunny day and when "Tiny" finished lunch, he walked right out of the restaurant without the hat.

Eight days later on his way back, he stopped in that same restaurant in Griffin, Ga., and there was the hat still on the same hook. "Proves," said "Tiny," "the effectiveness of those hat inserts."

* * *

See you all in Chicago on May 29th. My Girl, Gin, won't be there this year.—Sorry Fellows!—

V.T.Y.—Doc.



You can save money with

PITTCHLOR

water treatment

Here are just two of numerous conditions where Pittchlor will save you money:

1. Where less than 500,000 gallons of water are treated daily.
2. Where the available chlorine demand is not large.

Pittchlor does the same effective job as liquid chlorine—but saves on equipment investment required. Pittchlor is saving money for many water systems around the country.

A high-test calcium hypochlorite containing 70% available chlorine. Granular, free-flowing, non-caking. Packed in 5 lb. cans (9 per case), 3¾ lb. cans (12 per case) and 130 lb. drums.

Write for descriptive literature and any other specific information you want. Pittsburgh Plate Glass Company, Columbia Chemical Division, Fifth and Bellefield, Pittsburgh 13, Pa.

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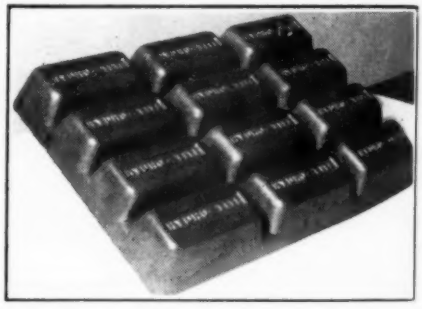
MANUFACTURERS' and EQUIPMENT NEWS

500

"Hydro-Tite" in Handy Chocolate Bar Form

Hydraulic Development Co., 50 Church St., New York, N.Y., has announced a new packaging form for "Hydro-Tite," the jointing compound. It is now available in solid form. The new package weighs 50 lbs. and contains 24 handy-sized ingots weighing approximately 2 lb.



each. These ingots come twelve to a cake and can easily be separated like the squares of a chocolate bar. The new package is easier to ship, store and handle, and the smaller ingot simplifies melting operations.

Granular "Hydro-Tite" will continue to be available in 100-lb. moisture-proof bags. As in the case of the new ingot form of "Hydro-Tite," the granular form is now also fortified with an effective germicide at no extra charge. The germicide is added to insure protection of the jointing material against *possible* bacterial attack, should hazardous soil conditions be encountered anywhere along the pipe line.

To obtain further information on this new package, use a Reader Service Card on which is entered the above key number, and your name and address.

In BOTH water supply and sewage Beckman pH control

Cuts treating costs... Saves chemicals... Increases efficiency

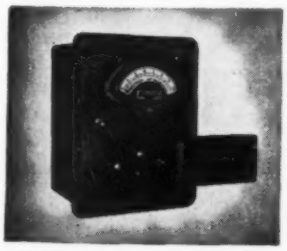
...IN WATER SUPPLY

In the main treating plant of the giant Metropolitan Water District of Southern California—a system capable of delivering a BILLION gallons of water per day across the entire state of California, and one of the largest water treating jobs in the world—the pH control equipment is 100% BECKMAN! In the mammoth treating plant where the water is softened and purified, Beckman Automatic pH Instruments control the pH of the liming process . . . of the carbonation process . . . and the pH of the final treated water. This 100% installation is notable tribute to the dependability of Beckman Equipment!

...IN SEWAGE TREATMENT

At its Stickney installation—world's largest sewage plant—the Sanitary District of Chicago tried Beckman pH Control on the chemical end of its sewage treating operations . . . found that it not only saved time and chemicals, but increased plant efficiency and decreased operating costs so successfully that a second installation was ordered for its Calumet Plant to cut operating costs there. Recently it ordered a THIRD Beckman pH Installation for still another plant in its large municipal system. Clear-cut evidence like that tells its own story!

LARGE OR SMALL, *YOUR* PLANT CAN SAVE WITH BECKMAN pH CONTROL!



The Beckman Automatic pH Indicator—Continuously and automatically indicates pH, and operates standard recording and control equipment for fully automatic pH control. Ask for Bulletin 161

The Beckman Industrial pH Meter—Ideal for portable plant and field use. Simple, rugged, accurate, and incorporates many unique operating features. Write for Bulletin 211

FREE! WHAT *EVERY* EXECUTIVE SHOULD KNOW ABOUT pH... simplifies the technicalities of modern pH control. Tells what is it, how it's used, where it fits into modern treating operations. Send for your free copy today!

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NATIONAL TECHNICAL LABORATORIES
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Beckman THE LEADING NAME IN pH

Cochrane Acquires Liquid Conditioning Corp.

Announcement has been made that Cochrane Corp. of Philadelphia has acquired substantially all of the capital stock of Liquid Conditioning Corp. of Linden, N.J. Hereafter the Liquid Conditioning Corp. will operate as a wholly owned subsidiary of Cochrane. Products of the company will continue to be marketed under the name "Liquon."

Engineering, sales, and technical staffs of the two corporations will augment each other. S. B. Applebaum, one of the organizers of Liquid Conditioning, will be in charge of the cold water conditioning activities of both organizations. Liquon district sales offices are combining operations with existing Cochrane sales offices.

J. G. Kirkpatrick to Represent Brooks Rotameter

Brooks Rotameter Co. of Lansdale, Pa., has announced the appointment of John G. Kirkpatrick as exclusive representative in the Pittsburgh area, including western Pennsylvania and West Virginia.

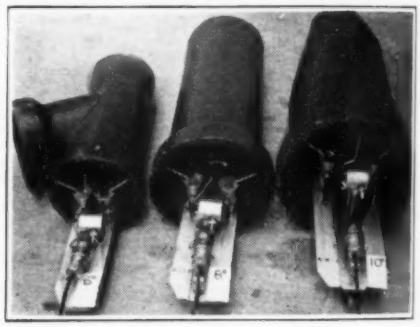
Mr. Kirkpatrick was formerly instrument engineer for the Koppers Co.

501

Wye and Tee Locator

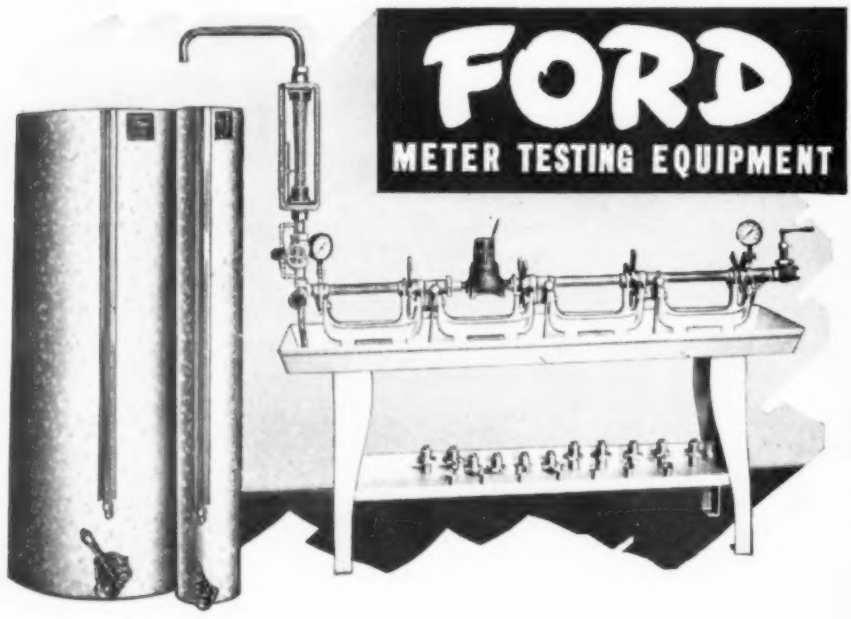
Alex W. Ely, 1604 Hoyt St., Madison, Wis., has developed a very unique device to locate branches and laterals in sewers. Known as the "Wyeget," this device, shown in the accompanying photographs, will locate the position of all wyes, crosses, and tees on a sewer line at the rate of 10 feet a minute.

The device is inserted in a sewer and is pulled upstream. Adjustable spring-loaded feelers make contact with the sides and top of the pipe.



When a feeler encounters an opening, it swings into the gap. This swinging motion turns a cam which makes an electrical contact and sends a signal through the taught trailing cable to an indicator box mounted over the rear manhole. A counter which reads to 1/10 of a foot measures the distance from the manhole to the opening. The feelers and associated cams and springs and switches are contained in "units" mounted on a plate that stays horizontal in the pipe. Different lengths of legs for the feelers are used for different sizes of pipe. Signalling current is supplied by low voltage batteries which permit operation under water or when the sewer is running full.

The Wyeget has been found to be exceedingly useful in making sewer



FLEXIBLE . . . for any size shop

Ford testing equipment is completely flexible in that it offers utmost economy of testing in any size shop.

FREE . . . .
Complete Ford catalog No. 50 of time and money saving meter equipment

Whether you test meters one at a time or in batteries of 10 or more, Ford provides complete accuracy, fast changing and easy visibility. Ford eliminates scales, weights and percentage beams and guess work.

Just tell us about your testing shop and we show you how to save time and money. No obligation, of course.

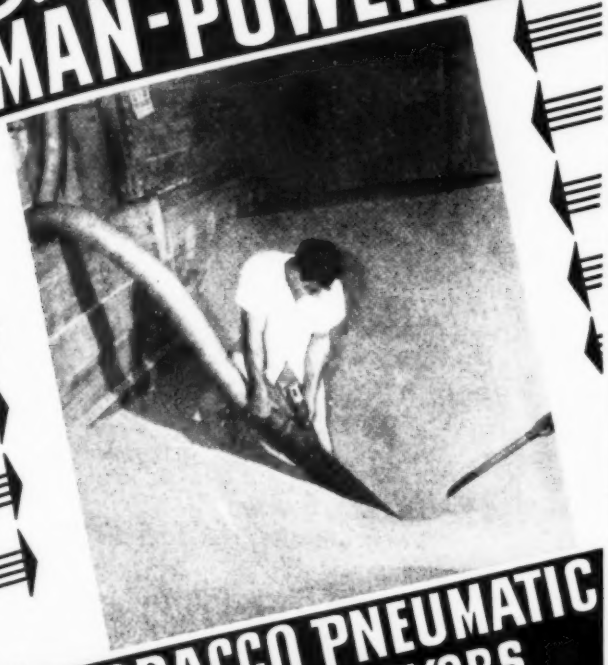
THE FORD METER BOX COMPANY, INC.

FOR BETTER WATER SERVICES

FORD

Wabash, Indiana

Save . . . MAN-POWER



With DRACCO PNEUMATIC CONVEYORS

The following Chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime, soda ash, bauxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

A PARTIAL LIST OF *DRACCO* INSTALLATIONS

FRIDLEY FILTRATION PLANT	Minneapolis, Minn.
DALECARLIA FILTRATION PLANT	Washington, D. C.
MUNICIPAL WATER SOFTENING PLANT	Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT	Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
MUNICIPAL WATER PLANT	Columbus, Ohio
MUNICIPAL WATER PLANT	Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT	Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT	Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
MINNEAPOLIS-ST. PAUL SANITARY DISTRICT (Sewage Disposal Plant, 2 installations)	St. Paul, Minn.
MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT	Denver, Colorado
MUNICIPAL WATER PLANT	Covington, Ky.
MUNICIPAL WATER PLANT	Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT	Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations)	Cleveland, Ohio
MUNICIPAL WATER PLANT	Benton Harbor, Mich.
MUNICIPAL WATER PLANT	Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich.
MUNICIPAL WATER PLANT	Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
CITY OF GRAND FORKS	Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT	Pit'sburgh, Pennsylvania
WATER FILTRATION PLANT	Wichita, Kansas
INDIANAPOLIS WATER CO.	Indianapolis, Ind.
WATER FILTRATION PLANT	Appleton, Wis.
MUNICIPAL WATER PLANT	Chillicothe, Ohio

Write for Bulletin No. 526

DRACCO CORPORATION

4079 E. 116th St., Cleveland 5, O. • New York Office, 130 W. 42nd St.

PNEUMATIC CONVEYORS • DUST COLLECTORS

Hooker Chlorine
A Multipurpose Chemical in Sewage Treatment

You who have the responsibility of sewage disposal as well as water sterilization will find Hooker Chlorine a multipurpose ally in making your work easier and your results better.

Sewage officials are using chlorine in many phases of sewage treatment to good effect. Chlorination of effluent is not only reducing bacteria count, but where residual is maintained at 0.5 to 1.5 ppm, indications are that there is a decided improvement in the quality of the water in which the effluent is discharged.

Stabilization of raw sewage, odor control, prevention of filter ponding and increasing filter bed efficiency, improvement of sedimentation and sludge digestion are other operations in sewage treatment where chlorine is being successfully used.

Hooker chlorine whether for sewage treatment or for water sterilization, is of the same uniform high quality that has been protecting water supply for over a quarter of a century. Hooker's Technical Staff, too, is at your service on problems involving the handling of chlorine and the other Hooker Chemicals. For assurance of consistent high quality specify Hooker Chlorine.

HOOKER ELECTROCHEMICAL COMPANY

Buffalo Ave. & Ward St.
Niagara Falls, New York

New York, N. Y. Tacoma, Wash.
Wilmington, Calif.

HOOKER CHEMICALS

Chlorine
Caustic Soda Muriatic Acid

2829

surveys and avoiding costly excavation to determine the location of branches.

To obtain more information about this unusual device, mail a Reader Service Card, on which is entered the above key number and your name and address.

502

Plastic Filter Cloth

Filtration Engineers Inc., 155 Oraton St., Newark 4, N.J., has introduced a new heat resistant Vinyon-N filter cloth. These Vinyon-N fabrics are acid-resistant, and are available for rotary filters.

To obtain further information on this filter cloth, use a Reader Service Card on which is entered the above key number and your name and address.

P. S. Wilson Now Manufacturers' Agent

P. S. Wilson, Glen Ridge, N.J., has established an office as a manufacturers' agent for water works supplies in New Jersey, New York and Connecticut. Among the firms which Mr. Wilson represents at present are the Gregg Co. of Philadelphia, manufacturers of protective coatings, the Atlas Mineral Products Co. of Mertztown, Pa., manufacturers of Mineralead Hydro-Rings, and pipe jointing accessories; and the Bethlehem Fdry. Co. of Bethlehem, Pa., manufacturers of the Bethlehem Flow Tube.

L. E. Sennet Joins A. P. Smith

Succeeds Ed. Lee in Chicago Office

A. P. Smith Mfg. Co. has announced the appointment of Lowell E. Sennet as Sales Representative in the Chicago territory, to succeed

Edward F. Lee, who is retiring. Mr. Lee has represented the company in that area for many years.

Mr. Sennet, a graduate of Case School of Applied Science, has previously been associated with Ludlow Valve Mfg. Co., the Crane Co., and the Grinnell Co. His office in Chicago will be at 8 So. Dearborn St., and he will serve the states of Illinois, Wisconsin, Indiana, and Michigan.

503

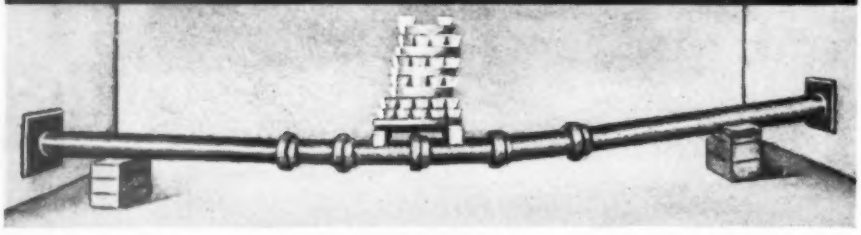
Trenching Machine

The Everett Manufacturing Co., Inc., Phoenix, Ariz., has developed a new trenching machine suitable for digging water, gas, sewer lines, and other kindred work. It has adjustable clearance teeth and digs from 12 to

18 in. in width and 42 in. deep, and will travel 1½ to 5 ft. per minute, depending upon the depth and width of cut and type of soil.

Further information on this new trencher may be obtained by using a Reader Service Card on which is entered the above key number and your name and address.

How Much STRAIN



Should your Bell & Spigot Jointing be able to Stand?

We made this experiment with identical parallel bell and spigot lines, the first joined with lead — the second with *Tegul*-MINERALEAD • Each line was loaded with pig lead as pictured. When the load reached 2000 lbs., the lead line gave way. The picture was taken when the weight on the *Tegul*-MINERALEAD reached 2285 lbs. • The loading was *continued* until at 5760 lbs. — nearly three times the weight capacity of the lead line — the *Tegul*-MINERALEAD line sank to the ground • Throughout the test better than 300 lbs. water pressure was maintained in the line and the *Tegul*-MINERALEAD joints developed no leaks, even upon collapse of the line • You can use this kind of endurance in your bell & spigot lines. You'll get it with *Tegul*-MINERALEAD, the original ingot form jointing compound • Write for complete information that may save you considerable bell & spigot jointing costs.

Tegul-MINERALEAD

Melts, pours and works easily in any temperature • Needs no caulking, deep bell holes or skilled labor • Can't change its correct composition under "rough riding" to the job.

THE *Atlas Mineral* *Products Company of Penna.*

PRODUCTS COMPANY OF PENNA.
*ATLANTA 3, Ga., 452 Spring St., N. W.
*CHICAGO 1, Ill., 333 No. Michigan Ave.

MERTZTOWN
*DETROIT 2, Mich., 2970 W. Grand Blvd.
NEW YORK 17, N. Y., 475 Fifth Ave.

PENNSYLVANIA
PITTSBURGH 27, Pa., 4921 Plymouth Rd.
ST. LOUIS 5, Mo., 7603 Forsythe Blvd.

THE ATLAS MINERAL PRODUCTS CO. OF TEXAS, INC. Box 252, Houston 1, Texas

OMAHA, Neb., 423 South 38th Avenue
DALLAS 5, Tex., 3921 Purdue St.
*DENVER 2, Colo., 1921 Blake St.
*HONOLULU 2, Hawaii, U. S. A.
*KANSAS CITY 8, Mo., 422 B.M.A. Bldg.
*LOS ANGELES 12, Calif., 172 S. Central Ave.
NEW ORLEANS 12, La., 208 Vincent Bldg.
OKLAHOMA CITY 2, Okla., 708 Braniff Bldg.
*SALT LAKE CITY 11, Utah, 925 S. 6th West St.
SAN FRANCISCO 7, Calif., 115 Townsend St.
*SEATTLE 4, Wash., 1252 First Avenue, S.
TUPELO, Miss., 517 South Spring St.

IN CANADA: Atlas Products are manufactured by H. L. BLACHFORD, Limited, 977 Aqueduct Street, Montreal 3, P. Q., 86 Bloor St. W., Toronto, Ont.
*Stock carried at these points

WRITE FOR OUR NEW CATALOG No. 25—Complete catalog describing detail features will be sent upon request

JOSEPH G. POLLARD CO., Inc.

Western Office—1064 PEOPLES GAS BLDG., CHICAGO 3, ILL.

MAIN OFFICE AND FACTORY—NEW HYDE PARK, N.Y.

Southern Office—1221 MORTGAGE GUARANTEE BLDG., ATLANTA 3, GA.

LABORATORY-TESTED *HOURLY!*

Gold Bond

HYDRATED AND QUICK LIME

Simplify your water purification problems
with one of these TESTED lime products.
Guaranteed uniform high calcium oxide content.
Write for information on your requirements.

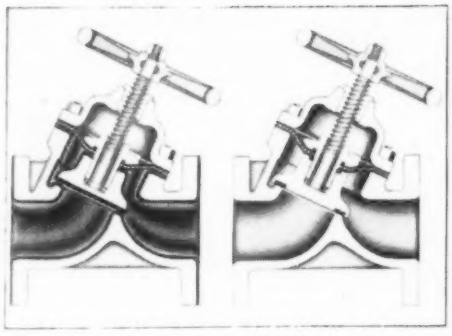
NATIONAL GYPSUM COMPANY, BUFFALO 2, N. Y.

High Calcium Lime Plants at Kimballton, Va., Bellefonte, Pa., and York, Pa.

504

Diaphragm Valve

Crane Co., Chicago, has introduced a line of diaphragm valves utilizing a new design principle that limits the diaphragm function to sealing the bonnet only. A separate seating member, giving positive control of flow independently of the diaphragm, reduces the flexing to which the diaphragm is normally subjected. Diaphragms last longer, closing is easier and quicker. Two types of valves are available, one in plain iron and the other neoprene-lined and coated.



The new Crane valves are for use with air, gases, corrosive fluids, corrosive waters, sludges, slurries, industrial wastes and sewage.

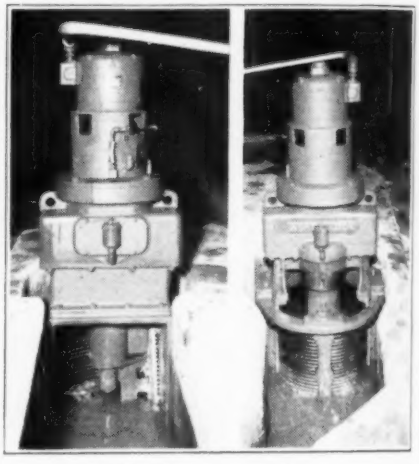
To obtain further information on these new diaphragm valves, mail a Reader Service Card on which is entered the above key number and your name and address.

505

Solids Comminutor

Worthington Pump & Machinery Corp., Harrison, N.J., has developed a new device for comminuting (cutting or shredding) coarse solids in raw sewage. This new unit is a compact, vertical device comprised of a screen, a mechanism for cutting the screenings, and an electric motor. Solids too large to pass through the horizontal slots are collected by an oscillating arm.

An advantage of this type comminutor is that the sewage is permitted to flow straight through the

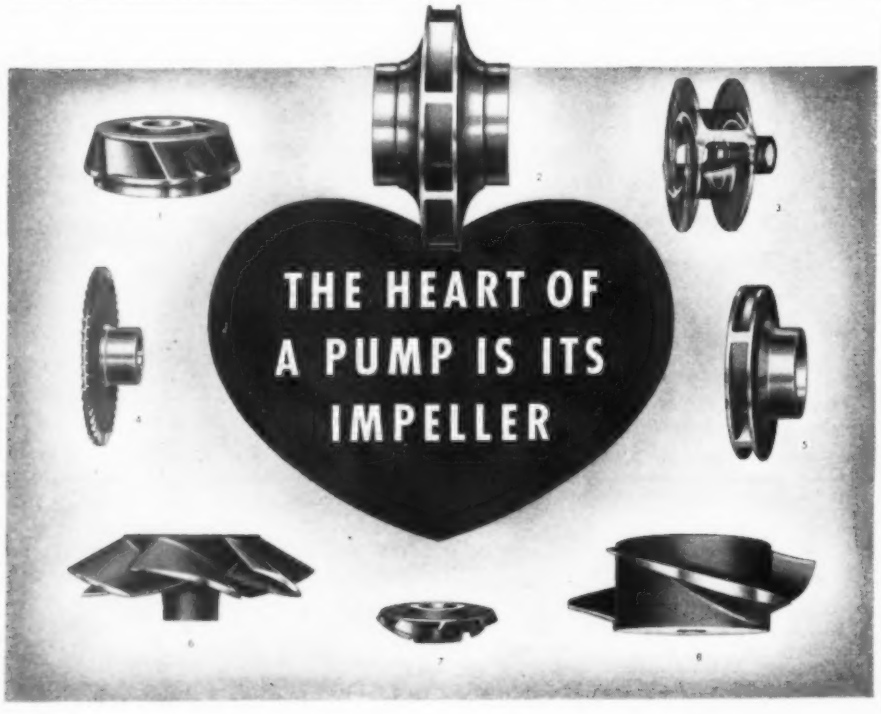


screen and the comminutor may therefore be installed in any straight rectangular sewage channel. This simplifies installation and minimizes cost. Cutters are readily removed for inspection, sharpening or replacement without draining the channel, and there are only two racks of cutters to the mechanism, thereby simplifying maintenance.

To obtain further information on this new unit, fill out a Reader Service Card and mail.

E. J. Lame of R. D. Wood Dies

Edwin J. Lame, Vice Chairman of the Board of R. D. Wood Co., died late in March at the age of 77. Mr. Lame entered the employ of the company as an office boy in 1887 and held many positions with the company until 1918 when he was elected vice president, a position he held until 1947 when he became vice chairman of the board.



Peerless Pumps utilize many different impeller designs to meet various fluid conditions

What makes a pump "tick?" Its heart is an impeller!

Pictured above are eight Peerless impeller designs for varying fluid conditions. No. 1 forces water upward from deep wells. No. 2 is a double suction design for high capacity horizontal pumps. No. 3 pumps solids in suspension. No. 4 handles all liquids in small capacities, at high heads. No. 5 is of single suction design for process services. No. 6 combines both radial and axial flow. No. 7 is a semi-open impeller for small diameter deep wells. No. 8 is an impeller that "propels" large liquid volumes.

The point is—capacities, lifts, heads, temperatures, chemical analysis, clarity, shaft speeds are seldom common to different pump services and installations. Because fluid conditions vary, Peerless pump designers are versatile and Peerless pumps utilize this versatility in different impellers for varying fluid conditions, successfully pumping most liquids in all industries.

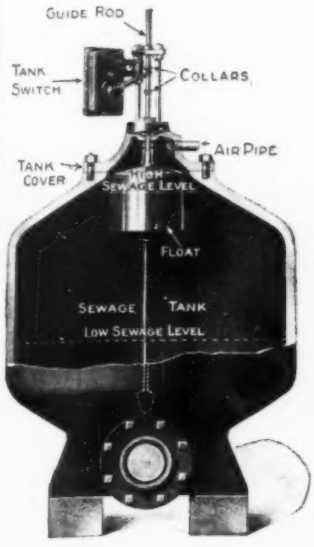
Plan with Peerless for all your needs for pumps. Select the pump you require from the comprehensive Peerless line of both horizontal and vertical type pumps. Individual descriptive bulletins are available on the type of pump you require. Request your copies today.

Peerless
VERTICAL AND HORIZONTAL
Pumps

PEERLESS PUMP DIVISION
FOOD MACHINERY AND CHEMICAL CORPORATION
Los Angeles 31, California Indianapolis, Indiana
District Offices: New York 5, 37 Wall Street; Chicago 40, 4554 North Broadway; *Atlanta Office:* Rutland Building, Decatur, Georgia; Omaha, Nebraska, 4330 Leavenworth St.; Dallas 1, Texas; Fresno, Calif.; Los Angeles 31, Calif.

PNEUMATIC SEWAGE EJECTOR

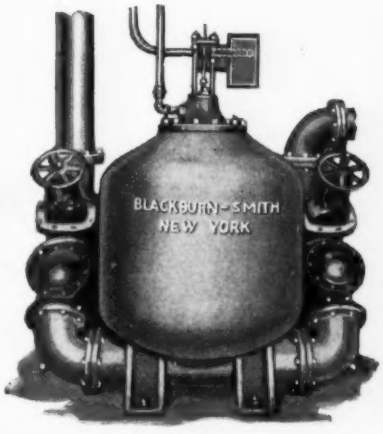
From 30 to 300 Gallons Per Minute in Single or Duplex Units



- Ejector Pots Empty in 30 seconds or less against very high heads handling heavy sewage or water.
- Furnished to operate with Electrodes, or Entirely Pneumatic.
- Years of Service with a Minimum of Attendance.
- Hundreds in Operation with Uninterrupted Service.

The BLACKBURN-SMITH EJECTOR

- ELIMINATES Cleaning Sewage Fouled Pumps and Screens.
- KEEPS OUT Sewage Contaminated air from compressors.
- INSURES Clean Valves and Floats.
- ECONOMICAL Electric-Pneumatic Operation.



Single Type

Write for catalog.

THE BLACKBURN-SMITH MFG. CO., INC.,
95 RIVER STREET, HOBOKEN, NEW JERSEY
Phones: HOboken 3-4425—REctor 2-9360

ASBURY SEWAGE PLANT

SAVES HIGH COST OF FREQUENT REPAINTING

Ramuc Utility Enamel Applied in 1938 Still Giving Full Protection

Fume-resistant moistureproof Ramuc Utility Enamel keeps expenses down at Asbury Park Sewage Plant. Since Ramuc's light colors increase visibility the rooms where it is applied require less artificial light. Ramuc prevents steel from rusting and protects concrete from deterioration. Its tilelike finish makes cleaning effortless. And a paint job that lasts over 10 years is easy on the budget!

Ramuc color scheme at Sewage Plant, Asbury Park, N.J.: Ceilings and upper walls, ivory. Dado, lemon yellow. Striping, dark blue. Floors, French grey. Piping, light grey.

Ask for "Painting Guide"—FREE

INERTOL CO., INC.

480 Frelinghuysen Avenue
Newark 5, New Jersey

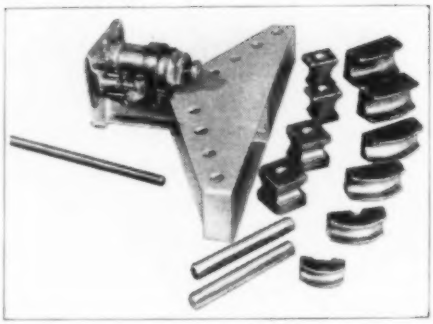
19 South Park
San Francisco 7, Calif.

506

Portable Pipe Bender

Electric Cord Co., 30 Church St., New York 7, N.Y., has introduced a new lightweight portable hydraulic pipe bender which bends standard pipe in sizes from ¾ to 2½ in. right on the job. The hydraulic jack can be easily removed from the frame and used for other purposes.

For further information on this new unit, use a Reader Service Card on which is entered the above key number and your name and address.

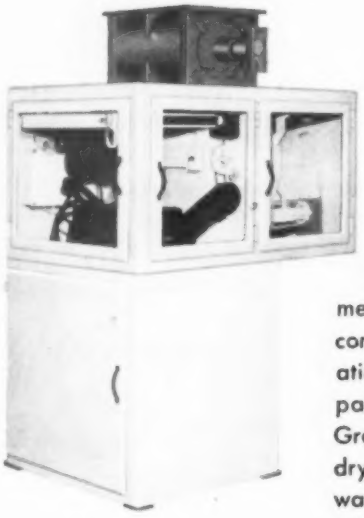


YOU BUY BY WEIGHT...

FEED BY WEIGHT

WITH OMEGA

CHEMICAL FEEDERS



OMEGA Belt Type Gravimetric Feeder

For accuracy of chemical feeding, for economy of materials, and for trouble-free service — install the OMEGA Belt Type Gravimetric Feeder. This dependable unit feeds by weight either fine or coarse materials with an accuracy of 98% or better. The unique operating mechanism and sensitive scales provide complete uniformity of feeding, eliminating wasteful overfeeding, costly stoppages, or underfeeding. With the Gravimetric Feeder you can handle any dry chemical commonly used in the waterworks—lime, ferric sulphate, soda ash, alum, etc. Precise adjustments afford infinite variations in feeding rate over a 100 to 1 range . . . standard units feed from 10 to 10,000 lbs. per hr.

Equip your Feeder with an Omega Dust Collector for easier housekeeping. Banishes bothersome dust and soon pays for itself in convenience and cleanliness.

Write for Bulletins.

OMEGA PRODUCTS

Volumetric Feeders • Gravimetric Feeders • Solution Feeders • Lime Slaking Equipment Bucket Elevators • Laboratory Stirrers

OMEGA MACHINE COMPANY

(Division of Builders Iron Foundry)

PROVIDENCE 1, R. I.

Chain Belt Announcement

Chain Belt Co. of Milwaukee has announced the opening of two new district sales offices, one at St. Louis, Mo., located at 8001 Clayton Road, St. Louis, under the direction of Clarence R. Studer, district sales engineer; and the other at 340 W. Church St., Jacksonville, Fla., under the direction of David B. Hill.

The company has also announced that its Los Angeles district office and warehouse has been moved to new and larger quarters at 3838 Santa Fe Ave., Los Angeles 11, Calif. J. V. McDonald, district manager, continues in charge of this office.

507

Portable Gasoline Breaker

Warsop Power Tools, Inc., 347 N. 12th St., Philadelphia 7, Pa., is offering a self-contained, portable, gasoline-operated breaker.

Weighing approximately 90 lbs., operating on a mixture of gasoline and a small amount of oil, and having a gasoline consumption of approximately two quarts per hour with an rpm. of approximately 2,250, this Warsop breaker can be relied on for breaking concrete, general demolition, trench spading, asphalt cutting, light ramming, driving ground rods, digging frozen and hard ground, etc.

For further information, use a Reader Service Card on which is entered the above key number and your name and address.

Superior Performance

TENNESSEE CORPORATION
Ferri-Floc
FERRIC SULPHATE
Atlanta, Georgia

...of a Superior COAGULANT

SEVEN ADVANTAGES OF FERRI-FLOC

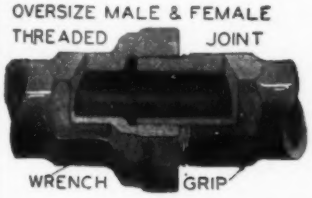
1. Coagulation is effective over a much wider pH range than with other coagulants. Color flocs may be formed in the very acid range where other coagulants may not be employed. On the other hand, true hydrated ferric oxide flocs may be formed at pH 9-10 or even higher for the removal of turpidity and manganese.
2. The time required for floc formation, conditioning and settling is in many cases considerably shorter than that required for other coagulants.
3. Filter runs have been markedly increased in several cases.
4. Manganese is successfully removed at pH values above 9.
5. Effluents may be produced which are exceedingly low in both iron and aluminum.
6. Hydrogen Sulphide is removed and taste and odors improved.
7. Ferri-Floc does not seem to stick to sand grain to form mud balls, and is subject to less "breaking through" on the filters.

Let us send you FREE, this valuable booklet on Ferri-Floc.
Write TENNESSEE CORPORATION,
Grant Bldg., Atlanta, Ga.

Many of the country's larger plants are now recognizing the advantages offered by Ferric Coagulants and are taking advantage of them through Ferri-Floc. — Ferri-Floc eliminates the troubles encountered with other coagulants by improving general quality, reducing overall cost. — All of this is accomplished without costly changes in plant equipment.

TENNESSEE CORPORATION
Atlanta, Georgia — Lockland, Ohio

EASY To MAKE TIGHT Joints WITH McWANE



2" THREADED JOINT Cast Iron Pipe

The cross-section view shows the simplicity, the rugged strength, and the sound engineering design of this modern THREADED JOINT. It is a joint any man can make with only a wrench, for all he does is "screw 'em together!"

McWANE CAST IRON PIPE CO.
BIRMINGHAM, ALA.

McWANE 2" CAST IRON PIPE

A CLEAN CUT IN 3 MINUTES Thru 18" Transite with SPRING LOAD A-C!

PAYS ITS COST ON ONE JOB!

Because it cuts many times faster than any other method, and requires but *one tenth* the maintenance, SPRING LOAD A-C means real economy. No preliminary multiple parts assembly necessary . . . takes but a few seconds to set up . . . one man can handle. Priced $59.50 for 3"-8" cutter. Extensions for handling larger pipe extra. Ask your jobber or write.

H. D. FOWLER CO., Inc.
P.O. Box 3084 Seattle 14, Wash.

Vandervoort Vice Pres. Marlow Pumps

Announcement has been made of the election of Vincent Vandervoort as vice president of Marlow Pumps, Ridgewood, N.J.

Mr. Vandervoort has been associated with the Marlow concern since 1947. He is also active in a number of organizations and for 20 years was associated with the Watson Machine Co. of Paterson, from which he retired as president a year and a half ago.

Layne & Bowler Acquire General Filter

Announcement has been made that Layne & Bowler, Inc., Memphis, Tenn., has acquired the General Filter Co. of Ames, Ia. This brings to a total of seventeen well water supply companies affiliated with Layne & Bowler, Inc.

The General Filter Co. was organized in 1935 by J. P. Lawlor, a former Layne engineer. He will remain as president of the company.

In addition to well water supply and equipment, the General Filter Co. also manufactures household soft water units.

John Purser Honored by Builders

At the annual dinner of Builders Iron Foundry honoring persons of long service to the company, a ten year service pin was presented to John R. Purser, Jr., of Purser & London, Inc., Charleston, N. C. Mr. Purser's organization is a well-known North and South Carolina representative for Builders-Providence, Inc., Omega Machine Co., and Proportioneers, Inc.

The photo shows the presentation being made by Henry S. Chafee, president of Builders Iron Foundry.

Caouette Gen. Mgr. Pittsburgh Equitable Meter

Announcement has been made of the appointment of Ralph G. Caouette as general manager of the Pittsburgh Equitable Meter Div. of Rockwell Mfg. Co.

Mr. Caouette has recently been general manager of the Red Star Products Div. at Norwalk, Ohio, and has had varied experience with Rockwell, having been production superintendent of the Delta Div. before coming to Pittsburgh. He has also been manager of industrial engineering for all of Rockwell Mfg. Company's plants.

WE'RE USING AMERICAN WATER METERS BECAUSE WE'RE STANDARDIZING ON QUALITY AND SIMPLICITY- NOT JUST A NAME
● By using Buffalo-made Meters throughout, you base your standardization on the higher meter earning power and other benefits that Buffalo's quality construction and simplicity of design will bring.
BUFFALO METER COMPANY
2909 MAIN STREET, BUFFALO 14, N. Y.
AMERICAN BRONZE CASE
NIAGARA GALV. IRON CASE
WATER METERS

LOW TEMPERATURE INCUBATION

is made convenient by the Cenco improved refrigerating incubator. Large capacity (7 cubic feet) provides for as many as 143 bottles of the B. O. D. type (#29003). It maintains a uniform constant temperature at 20° C within the specified variable of 1° C, and can be set at any temperature between 5° C and 50° C in a room of average temperature. For operation higher than 5° C above room temperature, the heat regulating system only need be used. The constancy is approximately ½° C.

No. 46042 Cenco Incubator, with forced circulation heating unit and two shelves, inside dimensions, 24x15x32 inches, for 115 volt, 60 cycle current, $435.00

CENTRAL SCIENTIFIC COMPANY

Scientific CENCO Apparatus

1700 IRVING PARK ROAD, CHICAGO 13

NEW YORK BOSTON SAN FRANCISCO NEWARK LOS ANGELES TORONTO MONTREAL

FOR SAFE FOOTING

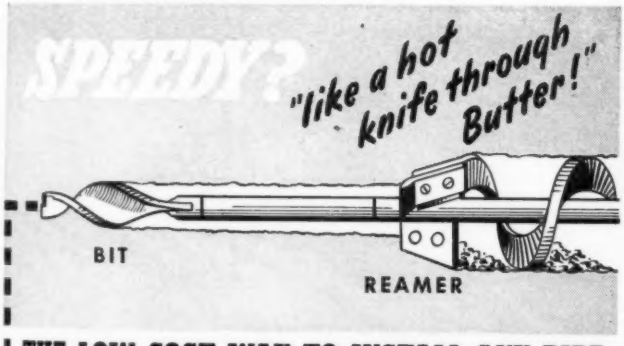
This one-piece electroforged steel "material" is furnished to your specifications—cut to fit any shape or area. Installation is quick and sure—requiring only simple clips supplied with order . . . Safe footing at all times is assured by twisted cross bars . . . Admits maximum amount of light and air . . . Only maintenance is an occasional coat of paint . . . For safety's sake, mark your grating specs—"Blaw-Knox".

BLAW-KNOX DIVISION

of Blaw-Knox Company

2051 Farmers Bank Bldg.

Pittsburgh 22, Pa.



THE LOW COST WAY TO INSTALL ANY PIPE

Even the toughest earth formations, like rotten rock, are no obstacle to Hydrauger operations. In fact, Hydrauger has fewer limitations, especially in time and costs, than trenching; and it is more certain than pipe-pushing, particularly if the pipe is coated, wrapped or of large size.

Write for Catalog No. 8 TODAY!

HYDRAUGER CORP., Ltd.
681 Market Street
San Francisco 5, California

OPEN HOLE

*Hydrauger

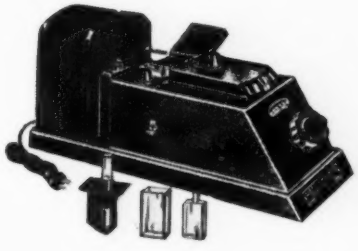
*Reg. U. S. Pat. Office

HY-13A

EARTH BORING TOOL

KLETT SUMMERSON ELECTRIC PHOTOMETER

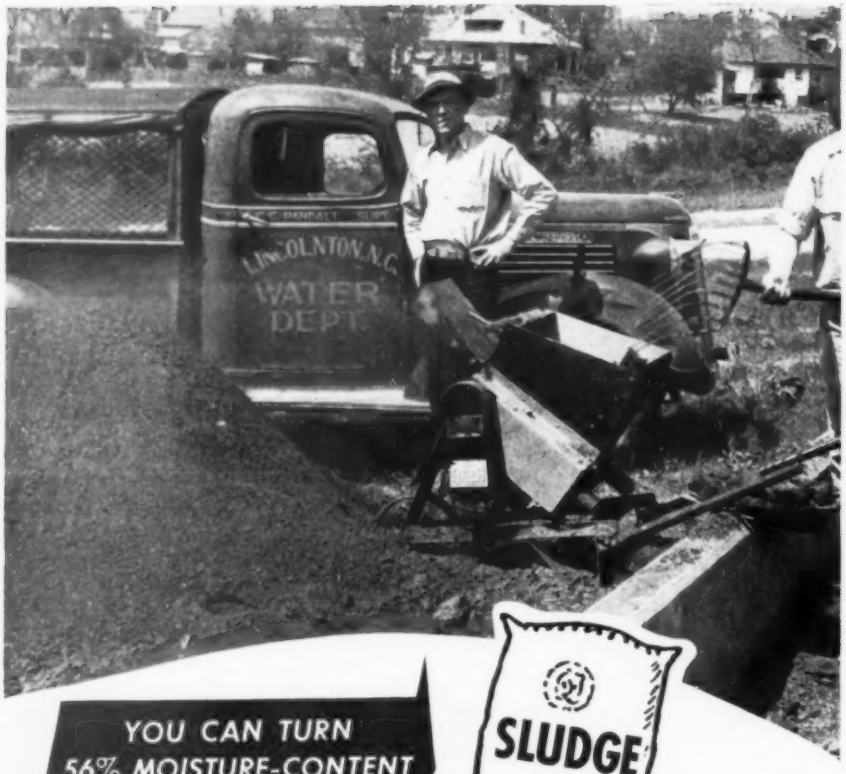
Adaptable for Use in Water Analysis



Can be used for any determination in which color turbidity can be developed in proportion to substance to be determined.

KLETT MANUFACTURING CO.

179 EAST 87th STREET • NEW YORK 28, N.Y.



YOU CAN TURN 56% MOISTURE-CONTENT SLUDGE CAKE INTO . .

SLUDGE FERTILIZER

with a **ROYER SLUDGE DISINTEGRATOR**

You can take sludge cake (up to 56% moisture) right out of your sludge beds and make it into marketable fertilizer . . . quickly . . . easily . . . and with less expense than it costs to burn unwanted sludge. Just shovel it into the hopper of a Royer, along with whatever commercial fertilizer is needed and the Royer does the rest—shredding and blending the materials and removing excess water. We'll be glad to send you full details on how it is done. Write us for Royer Sewage Sludge Datalog.

ROYER

PIONEERS IN THE SALVAGE OF SEWAGE SLUDGE

ROYER FOUNDRY & MACHINE CO.
170 PRINGLE ST., KINGSTON, PA.

ZECO GREENSAND ZEOLITE

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

ZEOLITE CHEMICAL CO.
Sales Office: 140 Cedar St., New York, N. Y.
Factory: Medford, N. J.
Pioneer Producer of GREENSAND ZEOLITE MINERAL

WATER MAIN DISINFECTION
COMPLETE SERVICE

(a) We will perform the complete job
or
(b) We will supervise only
or
(c) We will rent the equipment and furnish full instructions

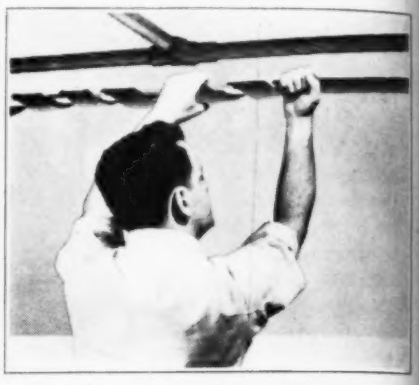
For complete information write

ALAN A. WOOD, INC.
1649 N. Broad Street, Philadelphia 22, Pa.

508

Stop Condensation Drip

J. W. Mortell Co. of Kankakee, Ill., has announced an improved cork-filled NoDrip Tape. More pliable than former products, it is now much easier to put on cold water pipes to stop dripping.



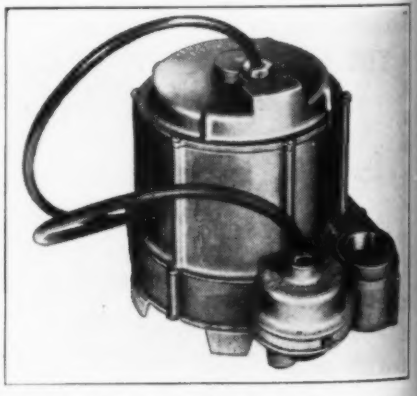
Applied when the pipe is dry, NoDrip Tape is clean and can be used on straight pipes, valves, joints, and tees without the use of tools, adhesives, or brads. NoDripTape is rich brown in color but can be painted any color with cold water paint.

To obtain further information on this material, use a Reader Service Card on which is entered the above key number and your name and address.

509

Submergible Sump Pump

Kenco, Inc., Elyria, Ohio, has announced the development of a completely submergible sump pump capable of continuous, uninterrupted operation. The turn-on point, or height of water required to start the



pump, is adjustable from a few inches to several feet. The diaphragm switch has no moving parts exposed to water and it is claimed that this is the only sump pump switch that does not require a float.

Only 9½ in. high and 11 in. in diameter, the unit has a capacity of

(*Continued on page* 131A)

RE
WA

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Please fill out a separate coupon for each item on which you desire information. This will greatly facilitate handling.

Key number is at head of each new product, item of equipment, catalog or bulletin, described in this issue.

Enter key number in box.

Please PRINT your name and title, company or department name, and your address

NOTE—

These cards are to be used only for items described in THIS ISSUE

WATER & SEWAGE WORKS

Will see that you receive information desired.

3,300 gal. per hour at 10 ft., and will pump water to a height of approximately 25 ft.

To obtain further information on this unit, use a Reader Service Card on which is entered the above key number and your name and address.

510

Residual Chlorine Recorder

Wallace & Tiernan Co., Inc., Newark 1, N.J., has culminated more than twelve years of research and development work on residual chlorine recording and now offers the "Amperometric Residual Chlorine Recorder", a device of which there are now several in successful operation. It provides a continuous, permanent record of actual chlorine residuals, either free available or total residual chlorine.

The recorder consists of a cell and a recording mechanism, and optional accessories include a Remote Residual Indicator and a Remote Alarm System.

By providing a continuous sample of water under test, the residual chlorine is determined constantly and recorded in terms of ppm. on a 24-hour circular chart.

Advantages of using this type of recorder are better chlorination control, permanent record of performance, check on operating irregularities, check on usage to avoid wastage, etc.

To learn more about this unique new device, use a Reader Service Card on which is entered the above key number and your name and address.

For Industrial And Municipal Water Treatment Plants

Alhydro FLOC PRODUCER

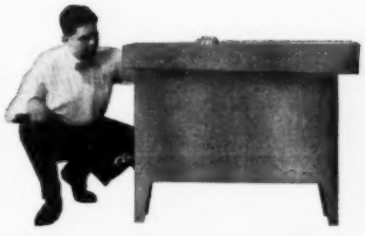
produces FLOC electrolytically

. . . . REDUCES CHEMICAL STORAGE PROBLEMS SAVES MONEY ON FREIGHT AND HANDLING COSTS

Check

THESE ADVANTAGES . . .

- Easily controlled production of completely stable floc regardless of water temperature, clarity or pH over a wide range.
- Better water at competitive costs.
- Usually eliminates need for correcting water before or after treatment.
- Simplicity of operation.



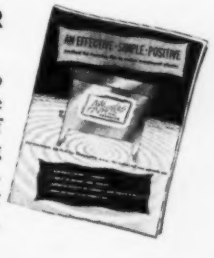
ONLY SO BIG... ***yet one unit treats an average of 300,000 gals. per day*** . . . and Alhydro may be installed in single or multiple units in existing or proposed water treatment plants.

Low-voltage d.c. current and aluminum plates are the only materials required to operate the Alhydro Floc Producer in practically every case. The Alhydro unit relieves you of paying freight and providing storage for bulky chemicals . . . completely eliminates the need for chemical feeders.

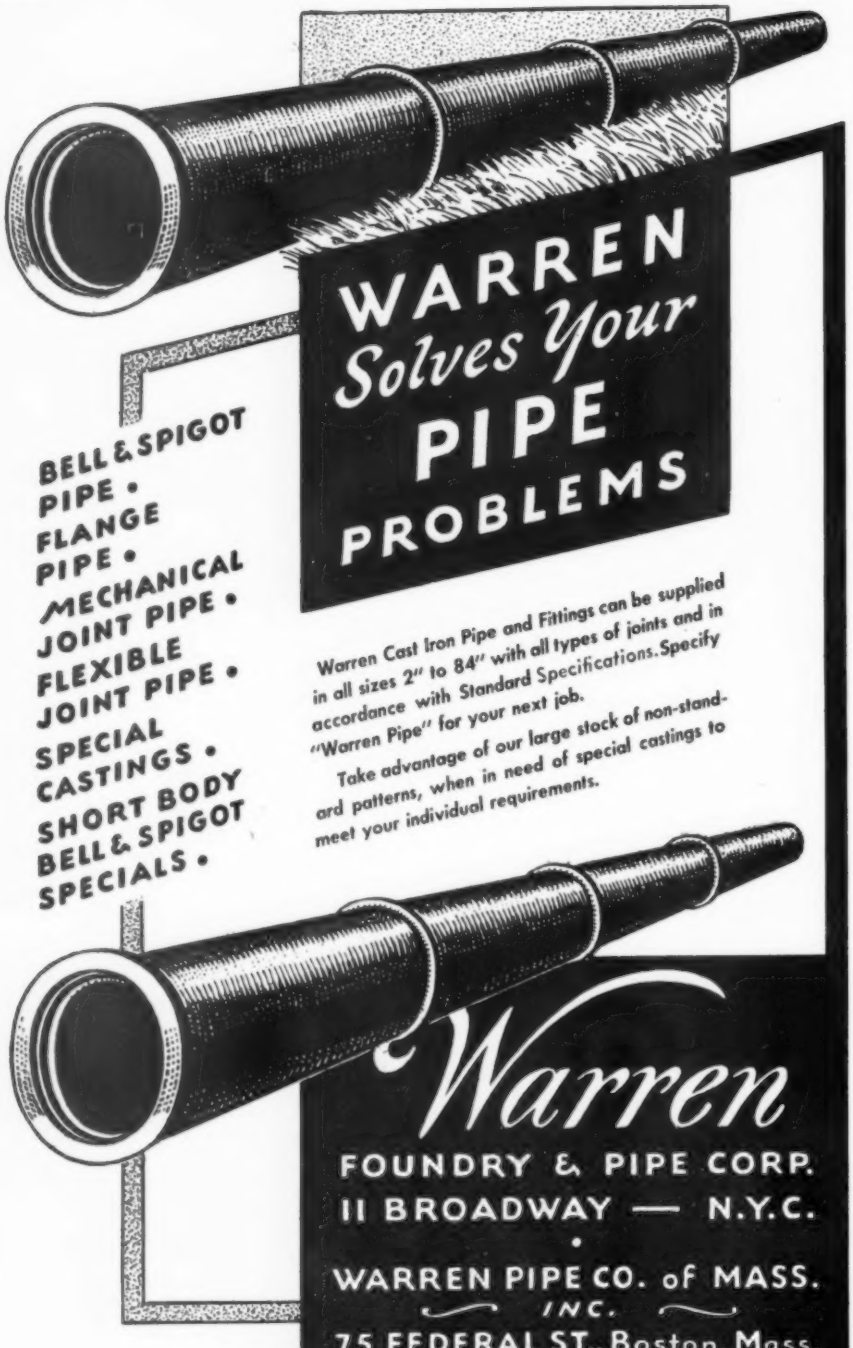
Maintenance costs fade, too, because only a minimum of attention and maintenance are needed for the production of concentrated aluminum hydroxide floc. Floc concentration may be controlled by varying current volume.

• WRITE FOR FOLDER . . .

See how Alhydro can simplify the treatment of water for drinking or industrial use. Write for your free copy today.



ALHYDRO, INC. DEPARTMENT 5B
516 N. CHARLES ST., BALTIMORE 1, MD.



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BELL & SPIGOT PIPE •
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FLEXIBLE JOINT PIPE •
SPECIAL CASTINGS •
SHORT BODY BELL & SPIGOT SPECIALS •

Warren Cast Iron Pipe and Fittings can be supplied in all sizes 2" to 84" with all types of joints and in accordance with Standard Specifications. Specify "Warren Pipe" for your next job.

Take advantage of our large stock of non-standard patterns, when in need of special castings to meet your individual requirements.

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FOUNDRY & PIPE CORP.
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•
WARREN PIPE CO. of MASS.
INC.
75 FEDERAL ST., Boston, Mass.

F. A. Arnesen Joins Worthington-Gamon

Worthington-Gamon Meter Co., Newark, N. J., has announced the addition of Fred A. Arnesen to its sales staff. Mr. Arnesen, who has been connected with meter sales since 1920, will make his headquarters at Oklahoma City and will represent the company in western Oklahoma, northern Texas and Louisiana, and parts of Arkansas.

511

Sump Pump

Fairbanks-Morse Co., Chicago, has announced a new cellar drainer or sump pump.

Having a high capacity of 4,200 gal. at 5 ft. discharge head, new type vulcanized rubber, positive control

floats, and bronze impeller of open construction, this unit is designed to be used in 12 in. drain tile.

To obtain further information on this new unit, mail a Reader Service Card on which is entered the above key number and your name and address.

ANTHRAFILT
Trade Mark Reg. U. S. Patent Office
A Filter Medium For All Purposes

ANTHRACITE EQUIPMENT CORP.
Anthracite Institute Building
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822 E. 8th St. Erie, Pa.
Engineers and Sales Agents

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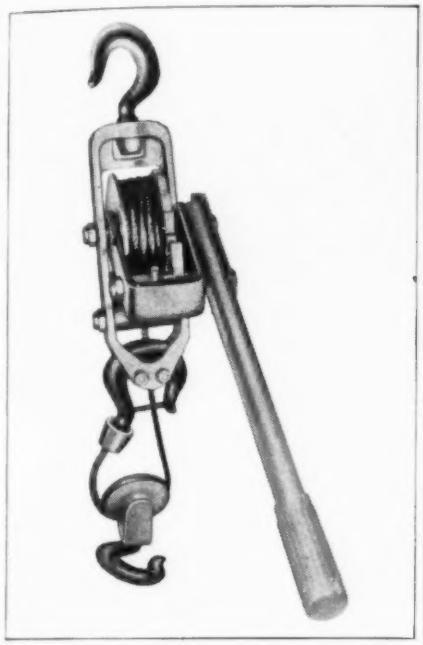
LEAKAGE
USE
CARSON CLAMPS
With Pearlitic C.I. Bolts for Cast Iron Pipe and Fittings.
Write for Prices.
Carson-Cadillac Co.
1221 PINSON ST. BIRMINGHAM, ALA.

512

Portable Hoist

Lincoln Precision Machine Co., North Grafton, Mass., has developed a portable hoist weighing only 8½ lbs., but capable of lifting one and one-half tons.

Designed with a minimum of parts and constructed of alloy aluminum, this unit is known as the "Lug-All". Instead of a chain which might kink, the Lug-All construction employs a 133-strand aircraft cable which reels



out without snagging. Limit for the cable is 15 ft., at which length the hoist capacity is 1,500 lbs.

To obtain further information on this new unit, mail a Reader Service Card on which is entered the above key number and your name and address.

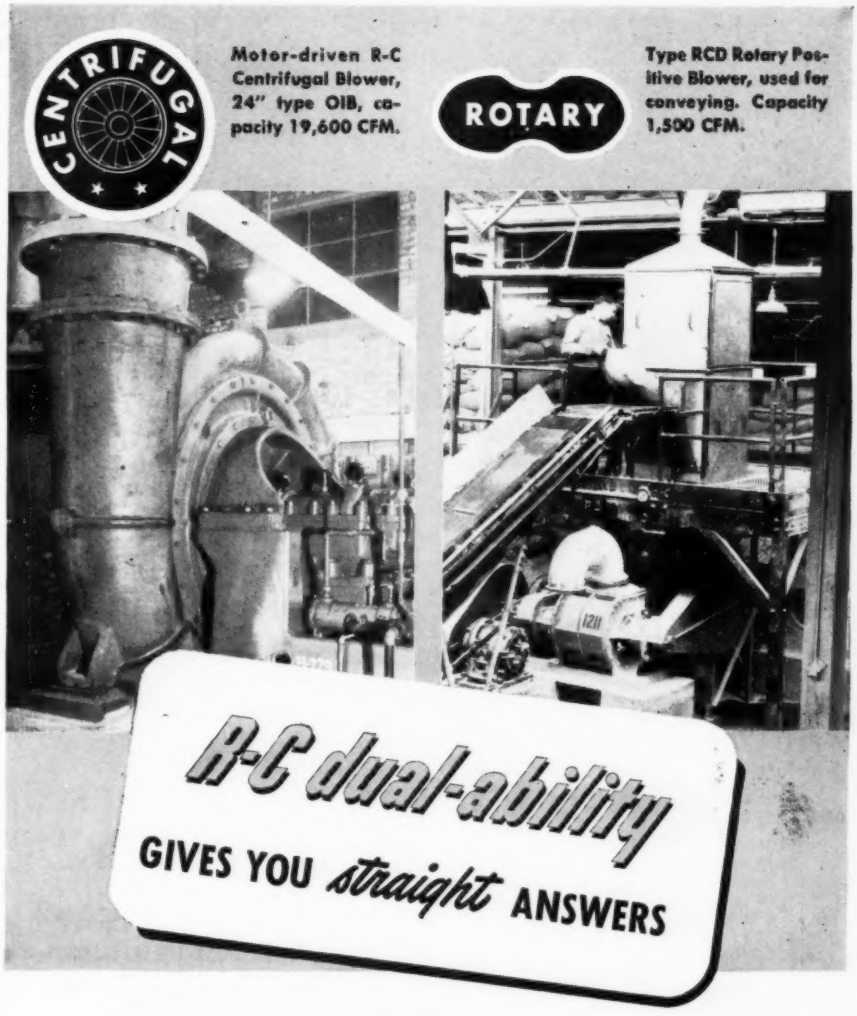
New Appointments at Atlas Mineral Products

Atlas Mineral Products Co. of Mertztown, Pa., has announced the appointment of F. C. Card, as district manager of materials of chemical construction sales in the New York and New England territory.

At the same time, Philip E. Berens was appointed district manager for eastern Pennsylvania and western New York.

Mr. Card was formerly assistant production manager of the Wanamaker Chemical Co., and Mr. Berens was formerly manager of the Electro Chemical Corp.

Mr. P. E. Wilson has been appointed representative for water pipe jointing material sales in the New York area.


CENTRIFUGAL
Motor-driven R-C Centrifugal Blower, 24" type OIB, capacity 19,600 CFM.
ROTARY
Type RCD Rotary Positive Blower, used for conveying. Capacity 1,500 CFM.
R-C dual-ability
GIVES YOU straight ANSWERS

Centrifugal or Rotary Positive? Which type of air or gas handling equipment is best suited to your needs? The answer depends upon the specific job—and you'll get the cold, unbiased facts from R-C *dual-ability*.

We can give you this *dual choice* because we build both —and we are the only blower manufacturers who do so. Further, our range of sizes, capacities, pressures and other characteristics is so wide that we can usually match or very closely approximate even exacting specifications.

By such fitting of equipment to the requirements of the job, you get superior performance, dependability and long life from your R-C units—the natural result of 95 years of blower-building experience.

ROOTS-CONNERSVILLE BLOWER CORPORATION
905 Mount Avenue, Connersville, Indiana

ROOTS-CONNERSVILLE

BLOWER BUILDERS R-C SINCE 1854

BLOWERS • EXHAUSTERS • BOOSTERS • LIQUID AND VACUUM PUMPS • METERS • INERT GAS GENERATORS

★ ★ ONE OF THE DRESSER INDUSTRIES ★ ★

"Lin" Murray Voted Schoellkopf Medal

R. Lindley Murray, executive vice-president of the Hooker Electrochemical Co., Niagara Falls, was named today winner of the Jacob F. Schoellkopf medal for 1949. The medal is awarded annually by the American Chemical Society for accomplishment in the field of science and research in industry.

Murray was cited "in recognition of his engineering ability and for his unusually able direction of chemical research and development in the chlorine and alkali industry."

SterElators by Everson

CHLORINE GAS DISPENSING APPARATUS
VISIBLE METERING BY ACCURATE METERS
VACUUM OPERATED SOLUTION FEED

MANUAL CONTROL
SEMI-AUTOMATIC
AUTOMATIC PROPORTIONING
WITH
AIR OR HYDRAULIC CONTROLS

METER RANGES
10 to 1 50 to 1 110 to 1

Everson SterElators measure, mix and feed chlorine gas to form a chlorine solution used to treat water supplies, industrial wastes, cooling water and sewage effluent. They provide the most advanced method of control and safety. Below are some of the more universally used types, namely

Series	Capacity Range in lbs. of Gas	Capacities Provided in each series
S	¼ lb. to 40 lb.	5
F	2 lb. to 100 lb.	9
O	15 lb. to 1000 lb.	7
E	100 lb. to 6000 lb.	4
K	5 lb. to 3000 lb.	5
P	2 lb. to 3000 lb.	5
AX	600 lb. to 18000 lb.	3

NO JOB TOO LARGE—SEND US COPY OF SPECIFICATIONS

Everson SterElator cabinets are made of heavy gauge pressed steel with removable panels, front, side and back. Cabinet sizes—18x18x72 and 20x27x72.

EVERSON MANUFACTURING CORPORATION
233 W. Huron Street Chicago 10, Ill. U.S.A.
Representatives from the Gulf to Canada and from Coast to Coast

513

Adapters for Big Meters

Ford Meter Box Co., Inc., Wabash, Ind., has developed adapters for larger meters. The new adapters are Nos. 46, 47, and 67.

No. 46 adapters are for a one-inch meter to set in where a 1½-inch flange meter has been. The No. 47 adapters attach to a one-inch meter for installation where a two-inch meter has been, and the No. 67 adapters are for a 1½-inch meter to fit in the space where a two-inch flange meter has been.

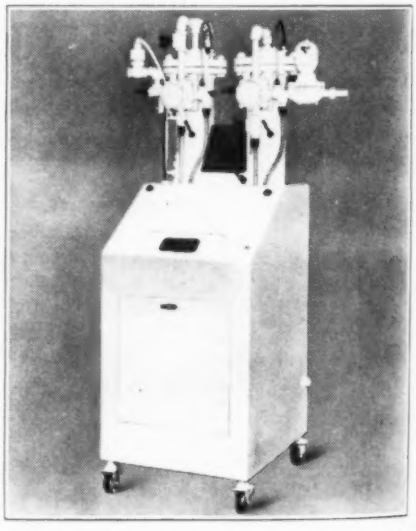
Ford Meter Box Co. has long made adapters for ⅝- and ¾-inch meters to increase the length of thread size to that of ¾- and one-inch meters.

To obtain further information on these larger adapters, use a Reader Service Card on which is entered the above key number and your name and address.

514

Demineralizing Unit

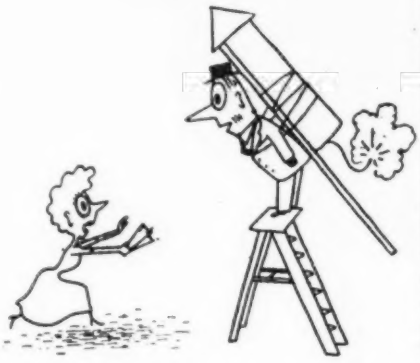
Belco Industrial Equipment Division, Inc., 102 Iowa Ave., Paterson 3, N.J., has announced the development of a new package demineralizing unit known as Model 200. This is a portable laboratory ion exchange unit for the production of a quality of water equal to distilled water in total solids.



The new Belco package demineralizing unit meets requirements for higher flow rates, having a maximum flow rate of 60 gal. per hour and an exchange capacity of 14,000 grains as calcium carbonate. Electronic controls assure automatic shut-off when a predetermined degree of impurity in the demineralized water is reached.

To obtain further information on this new unit, use a Reader Service Card on which is entered the above key number and your name and address.

Wait Henry!



There must be a better way to get to the A.W.W.A. Convention. You have until May 30th to get to Chicago, you know.

Combustion Engineering and Superheater Merge

Announcement has been made of the merger of the Combustion Engineering Co. and the Superheater Co., which henceforth will operate under the name of Combustion Engineering-Superheater, Inc.

The Combustion Engineering Co. is known in the field of sewage treatment for its flash drying systems and sludge incineration equipment.

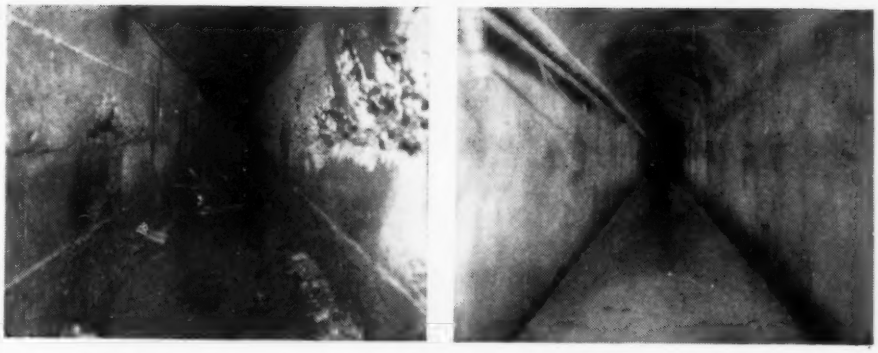
The company's offices will be at 200 Madison Ave., New York 16, N.Y.

N. J. Thompson Joins Dresser

Dresser Manufacturing Division, Bradford, Pa., has announced the appointment of N. J. Thompson as sales representative in the Rocky Mountain area and on the West Coast.

Mr. Thompson was formerly with the Thompson Pipe & Steel Co. and sales manager of the company for a number of years.

(*Continued on page* 136A)



Old Sewer Gets New Life with "GUNITE"

The picture at the left shows an old concrete storm sewer in Washington, D. C., badly disintegrated and honeycombed. Flow value was low due to roughness. This sewer was reconditioned by chipping away the worst areas, sandblasting the entire surface and applying a "GUNITE" lining.

The smooth brush finish increased its capacity sufficiently to meet all requirements, making it unnecessary to build a new sewer. The completed job is shown at the right.

Many money saving applications of "GUNITE" are described in our illustrated Bulletin C2400. Request on your letterhead will bring you a copy. .. ..

CEMENT GUN COMPANY
"GUNITE" CONTRACTORS
GENERAL OFFICES—ALLENTOWN, PENNA., U.S.A.
MANUFACTURERS OF THE "CEMENT GUN"

Increase Plant Efficiency

Boost Plant Capacity

with **CLOROBEN**

Mail coupon for **free** booklet showing how Cloroben can help **you**

THE CLOROBEN CORP.
15 Exchange Place
Jersey City 2, N.J.

Please send Free Cloroben Booklet to:

Mr...... **Title**.....

Address .....

Hazleton Type "M"

CHECK VALVE

with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

Flow switch insures pump against damage in event pump loses water during operation. Mercoid switch is actuated by valve-flap. Switch is connected into no-voltage coil of motor starter.

Write for Further Information

BARRETT, HAENTJENS & CO.
HAZLETON PENNSYLVANIA

In his new capacity Mr. Thompson will consult with water works operating personnel and engineers on both new line and maintenance problems. He will make his headquarters in Denver.

LITERATURE AND CATALOGS

515

MEASURING AND CONTROL EQUIPMENT

Simplex Valve and Meter Co., 68th and Upland Sts., Philadelphia 42, Penna., has just released a new **Simplex General Catalog** on Measuring and Control Equipment for Water and Sewage Works, Power and Processing Industries.

This 32-page catalog is a complete description of all Simplex devices used in the measurement or control of liquids and gases. Included in the catalog besides descriptions are pictures of the various units shown in cutaway drawings for explanation purposes. Among the items presented, described and discussed are Controllers, Flumes (Parabolic-Type S) Gauges, Manometers, Meters, Pitot Equipment, Turbine Taps, Valves, and Venturi Tubes.

To obtain a copy of this highly useful catalog, mail a Reader Service Card, on which is entered the above key number and your name and address.

516

OZONATION

The Welsbach Corp., Ozone Processes Div., 1500 Walnut St., Philadelphia 2, Pa., has issued a bulletin entitled **Ozone Purifies Water—Improves Taste.**

This bulletin contains the story of the use of ozone and ozonation at the Philadelphia water plant. This in-

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CONSULTING ENGINEER'S PRACTICE AND EQUIPMENT. LARGELY MUNICIPAL, IN PACIFIC NORTHWEST.

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22 West Maple Street, Chicago 10, Illinois

POSITION WANTED

Water Works supt. 9 years experience, age 38, single. Hold Texas Class "B" Water and "C" Sewerage Certificate.

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stallation went into operation in March. The bulletin shows the layout of the city and the water services, shows how the water was treated before and how it is being treated now with ozone being used, and gives a layout of future plans for the use of ozonation after the addition of more filters.

To obtain a copy of this bulletin, mail a Reader Service Card on which is entered the above key number and your name and address.

517

LUBRICATED PLUG VALVES

American Car & Foundry Co., Valve Division, 30 Church St., New York 8, N.Y., has issued a new bulletin on **"A.C.F. Full Pipe Area Lubricated Plug Valves".**

This new bulletin is complete in that it shows pictures and diagrams of the various valves and explains the many advantages of this type of installation for various usages.

A.C.F. also has a bulletin on the typical specifications covering A.C.F. lubricated plug valves and a list of sewage disposal plants which are fully or partially equipped with this type of valve for a number of services.

To obtain either or both of these bulletins, use a Reader Service Card on which is entered the above key number and your name and address.

518

NEUTRALIZING INDUSTRIAL WASTES

Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia 44, Pa., has issued a bulletin on **Effective Neutralization of Industrial Wastes.**

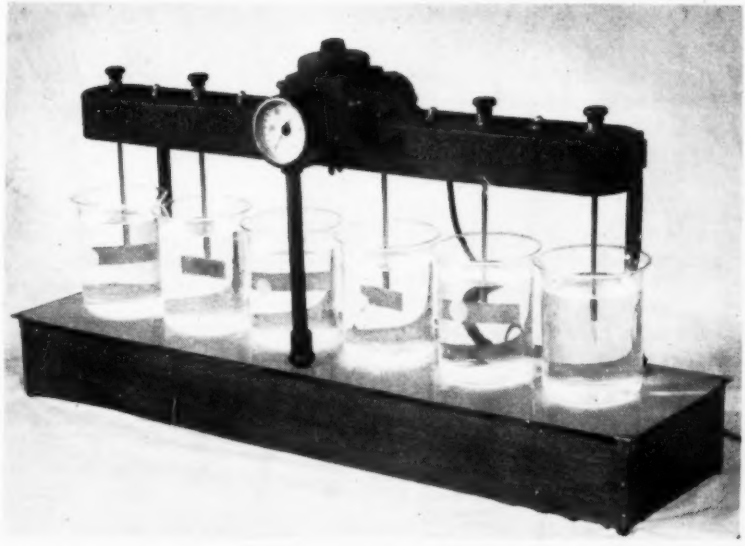
This bulletin describes the Micromax Automatic pH Control and discusses how automatic neutralization of waste is being used in many instances to combat stream pollution.

The bulletin also contains a discussion of the actual control results predicted by means of the controllability analysis, and a discussion of the equipment which is used to control pH of industrial wastes. Pictures and descriptions of several Micromax Pneumatic Controllers are presented.

Also included with the bulletin is a questionnaire on pH measurement which is of interest to industrial plants having waste problems.

To obtain a copy of this book on control of neutralization of industrial waste, mail a Reader Service Card on which is entered the above key number and your name and address.

THE *Phipps & Bird* LABORATORY MIXER - - -



IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of chemical dosages with this mixer. Write for literature.

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RICHMOND, VA.
"SOUTHERN CENTER FOR LABORATORY APPARATUS AND CHEMICALS"

settle your coagulating problem ...*fast*

Here's a quicker way to settle impurities (inorganic or organic) in raw water supplies or waste water. Coagulate with N-Sol (activated silica sol)*.

Activated silica sol, conveniently made by an N-Sol Process, and used with a coagulant such as alum or iron salts, speeds clarification. The larger, denser flocs which are formed enmesh the suspended solids better, and settle faster. Try N-Sol and measure these results:

Clearer effluent
Shorter settling time
Increased filter capacity

Let the flexible, efficient N-Sol solve a water treatment problem for you. Ask for a free copy of "Activated Silica Sol in Water Treatment".

*N-Sol Processes are methods by which "N" Silicate is reacted with ammonium sulphate, chlorine, or sodium carbonate to produce activated silica sol. This, together with alum, iron or lime rapidly forms a larger, denser, faster settling floc.

Philadelphia Quartz Co.
1166 Public Ledger Bldg.,
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N-SOL PROCESSES FOR WATER COAGULATION

519

AERATION TUBES AND PLATES

The Carborundum Co., Refractories Div., Perth Amboy, N.J., has available copies of Engineering Bulletin No. 1 on **Aeration of Sewage and Water with Porous Diffuser Plates and Tubes.**

This bulletin discusses applications of porous diffusers, aeration design, properties of Aloxite Brand porous diffusers, standard specifications, installation, and operation of service.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

520

HEAT EXCHANGER

The Dorr Company, 570 Lexington Ave., New York 22, N.Y., has issued a bulletin on **The Spiral Heat Exchanger.**

This bulletin shows the construction of the spiral heat exchanger, explains why external sludge heating is of benefit, and tells how this particular heat exchanger operates. Operating data are given and an installation is shown. The bulletin also contains a table of standard sizes and design data.

If you have a sludge digestion tank heating problem, you will be interested in this bulletin. To obtain a copy, use a Reader Service Card on which is entered the above key number and your name and address.

521

MULTI-POINTER GAGES

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio, has issued a bulletin on the **"Bailey Multi-Pointer Gages".** This bulletin describes the latest development in these gages which are described in detail as to different styles of casings and different units for various types of operation, including pressure, draft, or differential, etc.

To obtain a copy of this bulletin on these Multi-Pointer Gages, use a Reader Service Card on which is entered the above key number and your name and address.

522

WEED CONTROL

C. B. Dolge Co., Westport, Conn., has a bulletin available on **Chemical Weed Control.**

If your water or sewage plant is surrounded with a nice lawn ruined by weeds, then you will be interested in this bulletin. If you are troubled with poison ivy or ragweed at your plant, you will also be interested.

The Dolge bulletin on Chemical Weed Control tells of the different types of weed killers, the advantages of each, and tells where and how to apply them. One of the illustrations is of the water plant at Mt. Clemens, Mich., where the weed killer is being used on the lawn.

To obtain this interesting booklet on chemical weed killing, use a Reader Service Card on which is entered the above key number and your name and address.

523

CLARIFIER

Yeomans Bros. Co., 1431 N. Dayton St., Chicago 22, Ill., has an article in **"The Yeomans Guard"** on the new "Spiraflo" Clarifier manufactured by the company.

This article shows an installation of one of these clarifiers and describes the method of operation.

To obtain a copy of this article, use a Reader Service Card on which is entered the above key number and your name and address.

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Combination Corporation Stop and Saddle
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It's quick . . . it's simple . . . it's safe. It's the corporation stop that water companies and municipalities have needed for a long time. Especially today, with the large scale housing projects and the demand they put on the service department, the Hays "Duo-Stop" is an important time-saver in making connections to small mains.

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524
CONCRETE PIPE

United States Concrete Pipe Co., 1500 Union Commerce Bldg., Cleveland 14, Ohio, and the Universal Sewer Pipe Corp., at the same address, have issued a bulletin on **Plant Facilities** showing the location of the various plants of these two companies which manufacture sewer pipe and concrete pipe. Pictures of the several plants are shown.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

525
MOBILE RADIOTELEPHONE

Federal Telephone and Radio Corp., Clifton, N.J., has issued a bulletin on the **Federal FM Radiotelephone Communications Equipment.**

This bulletin describes both 2-way and 3-way communications equipment manufactured by Federal Telephone & Radio Corp. This type of equipment has been used to advantage in many water plants for hastening repairs and aiding in main cleaning, and general service between the shop and the repair trucks.

To obtain a copy of this bulletin on the mobile radiotelephone, use a Reader Service Card and mail.

526
STOP THAT LEAK!

Stauffer Mfg. Co., 8424 Otis St., South Gate, Calif., has a 4-page bulletin entitled **"Stop That Leak!"** devoted to the use of Stauffer Pipe Repair Clamps.

The catalog shows the different types of Special pipe repair clamps and the Superior pipe repair clamp for different types of service. There is also shown the Adams broken pipe clamp.

These pipe repair clamps are convenient, economical, and give permanent stoppage to leaks.

For a copy of this bulletin, use a Reader Service Card and mail.

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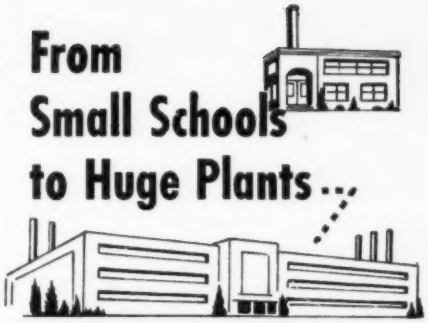

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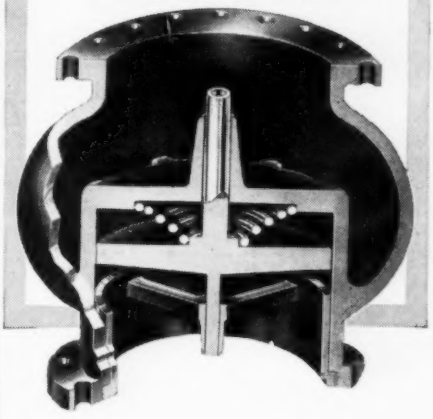

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527

WASTE TREATMENT

Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill., has announced the publication of a new bulletin, **Waste Treatment to Comply with Stream Pollution Control Regulations.** The bulletin describes briefly the general problems involved in waste treatment and then discusses principle methods of treatment. Actual case studies are used to explain these processes. The bulletin is intended primarily to inform the industrial plant executive and municipal engineer or anyone charged with responsibility for pollution control, of the latest important methods of waste treatment.

To obtain a copy of this interesting bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

528

VALVES AND GATES

Westinghouse Electric Corp. has issued a new 8-page booklet entitled **"Valves and Gates for Hydraulic Equipment".**

This booklet introduces a new line of Westinghouse products which are manufactured at the company's newly acquired Sunnyvale Plant. The booklet contains information on butterfly valves, slide and sluice gates, cylinder gates, hollow jet free discharge valves, and other supplementary equipment for the control and handling of hydraulic projects.

To obtain a copy of this booklet, use a Reader Service Card on which is entered the above key number and your name and address.

529

BELL-PACK SLEEVE

Dresser Manufacturing Div. has issued a four-page bulletin on its **"Dresser 'Bell-Pack' Sleeve Style 126".**

The bulletin shows by cutaway drawings this bell-pack sleeve and how it is used to give economical fast and permanent repairs to split and broken bells, mechanical joints and couplings.

These new bell-pack sleeves are lighter weight and easier to install, according to the bulletin. Many other advantages are listed.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

530

PAINT PLANNING

The Valdura Division of the American-Marietta Co., 43 E. Ohio St., Chicago, has issued an interesting bulletin titled **"Plan Before You Paint Your Plant".**

This bulletin is offered for plant superintendents, maintenance engineers, and others who are faced with planning painting in an industrial plant which, of course, includes water and sewage works.

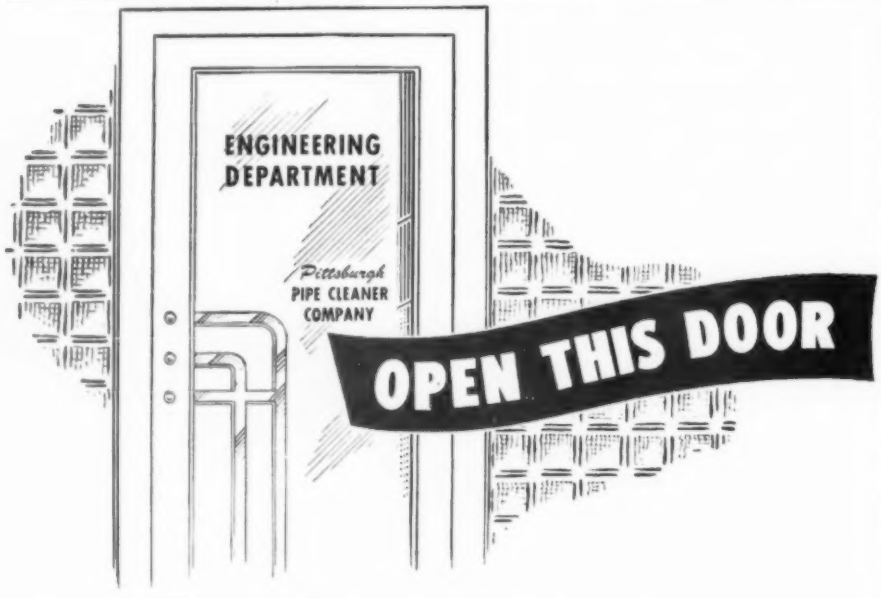
The booklet contains the "Dial-A-Tone" color selector, an ingenious device which makes color selection as easy as dialing a telephone. By working the dial, 108 tested foolproof color combinations can be viewed, with a choice of colors for ceiling, wall, and dado.

This interesting bulletin may be obtained if you will mail a Reader Service Card on which is entered the above key number and your name and address.

531

TELEMETER

Builders-Providence, Inc., Providence 1, R.I., has available a bulletin on **Builders "Chronoflo Telemeter."** This telemetering device is used to measure flow, liquid level, pressure, control pump, and chemical feed.



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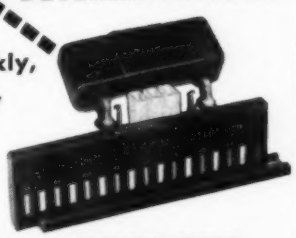

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The bulletin describes the action of the equipment and its many features, as well as showing pictures of the different designs and telling how it operates under various conditions.

To obtain a copy of this bulletin on the "Chronoflo Telemeter," use a Reader Service Card on which is entered the above key number and your name and address.

532

SLUDGE COLLECTOR

Link-Belt Co., Philadelphia Pa., has a bulletin on the **Link-Belt Straightline Collector for Settling Tanks.**

This bulletin shows the installation of these Straightline collectors, discusses primary and final settling tanks, shows longitudinal and cross collectors, gives data on capacity for settling tanks and pictures of installations where these are in use.

There is also a section on drive units, the conveying medium, and other Link-Belt sewage and water treatment plant equipment.

To obtain a copy of this bulletin on the Straightline collectors, use a Reader Service Card on which is entered the above key number and your name and address.

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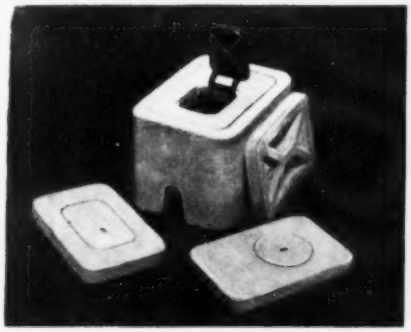

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533

PIPE COATINGS

Koppers Co., Inc., Tar Products Division, Pittsburgh 19, Penna., has a story in its **Bitumastic Bulletin** on a "New Water Works for Ancient Citadel." The story is about Quito, the ancient citadel of Ecuador, where a modern water works is being constructed. The article also discusses the various Bitumastic coatings used for protecting the pipe lines in the system.

If you are interested in this story and in pipe coatings, send for a copy of this "Bitumastic Bulletin." Just enter the above key number and your name and address on a Reader Service Card and mail.

534

"GUNITE"

Cement Gun Co., Allentown, Penna., has just issued a revised edition of its bulletin on the Cement Gun and **"Guniting."** This 66-page bulletin is profusely illustrated and covers the typical use of "Gunite." Sections of particular interest to water and sewage works authorities and operators are those devoted to pre-stressed tanks, reservoirs, swimming pools, concrete repairs, pipe lines, sewers, and steel encasement. This bulletin is a must for any one faced with concrete construction or repair problems.

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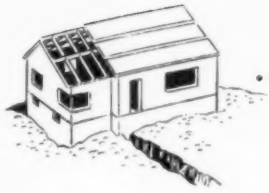

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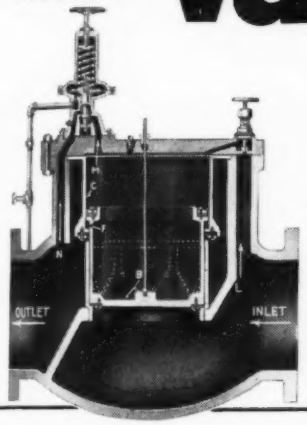

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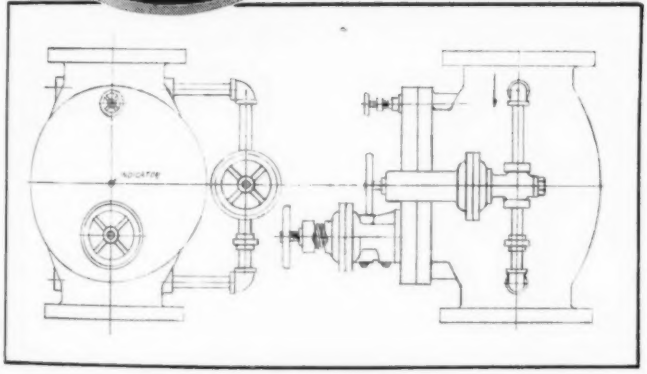

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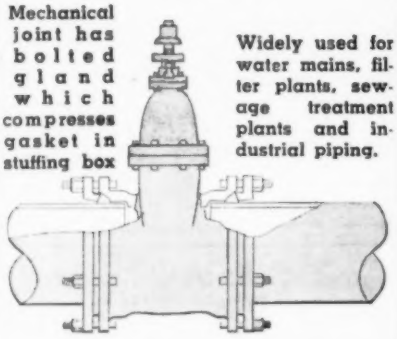

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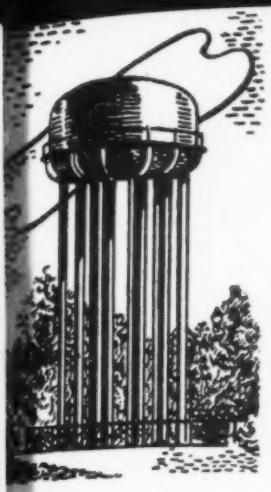

WATER & SEWAGE
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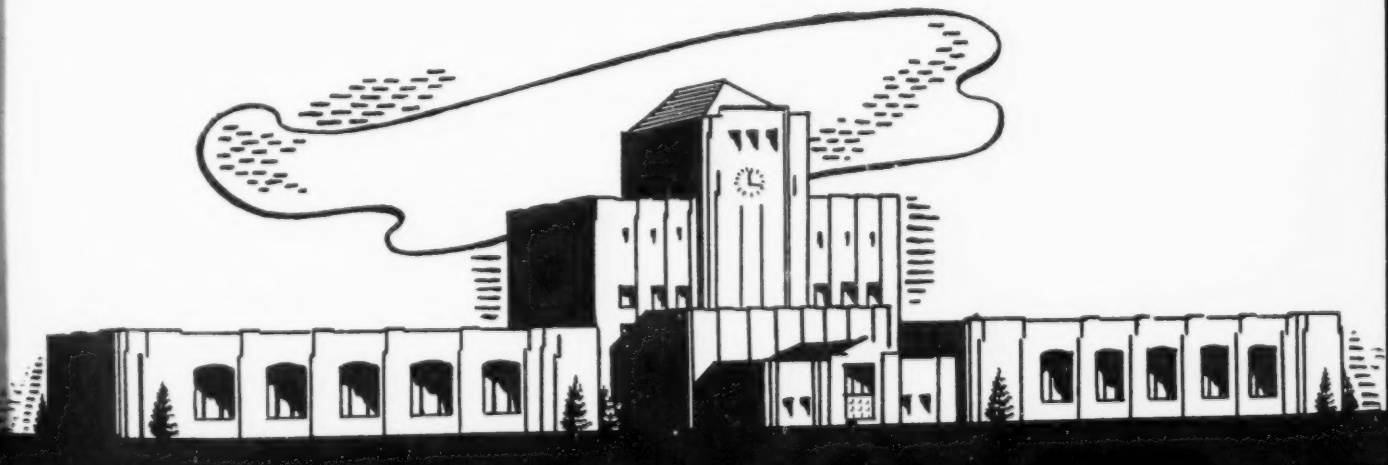

Foreword

In the past we have repeated useful basic data, tables, graphs, etc.—from year to year, chiefly for the benefit of new subscribers; certain other matter was repeated in alternate years or every third year, and new material was, of course, added. Thus the subscriber who kept three consecutive Reference and Data issues on file had all of the most important reference material published by Water & Sewage Works.

This year very little material is repeated from previous issues, but considerably more new material is being published.

In order to have a complete Reference and Data file it will be necessary for the readers to have available not only the current issue but also issues of at least the three years preceding this issue. Several articles published since 1941 have not been repeated within the last four years. Therefore for the convenience of the user a consolidated nine year index is incorporated in this issue.

CLASSIFIED INDEX of PRODUCTS

FOR THE INDEX TO THE REFERENCE AND DATA MATERIAL, AND THE INDEX TO ADVERTISERS, SEE THE REAR SECTION OF THIS ISSUE.

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(See Compressors, Air)

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(See Black Alum)

ALUM, FILTER
(See Filter Alum)

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Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

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Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold, 2413 W. Carson St., Pittsburgh 4, Pa.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Terminal Annex, Los Angeles, Calif.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

CHLORINATORS
(See also Hypochlorinators)
Amer. Water Softener Co., Philadelphia 33, Pa.
Builders-Providence, Inc., Providence 1, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

CHLORINE DIOXIDE
(See Sodium Chlorite)

CHLORINE, LIQUID
Diamond Alkali Co., Pittsburgh, Pa.
Hooker Electrochemical Co., 9 Union St., Niagara Falls, N. Y.
John Wiley Jones Co., Caledonia, N. Y.
Mathieson Chem. Corp., 60 E. 42nd St., New York 17, N. Y.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York.

CHLORINE CONTROL EQUIPMENT
(See Residual Chlorine Control)

CHUTES, COAL, ETC.
R. D. Cole Mfg. Co., Newnan, Ga.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Posey Iron Works, Inc., 560 S. Prince St., Lancaster, Pa.

CLAMPS AND SLEEVES, PIPE
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Grinnel Co., Inc., 260 W. Exchange St., Providence, R. I.

CLAMPS, PIPE REPAIR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.

CLARIFIERS SEWAGE AND WATER
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANING COMPOUNDS
C. B. Dolge Co., Westport, Conn.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Oakite Products Corp., 73 Thames St., New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Solvay Sales Div., 40 Rector St., New York 6, N. Y.

CLEANING SEWAGE MAINS
(See Sewer Cleaning Equipment and Service)

CLEANING WATER MAINS
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York City.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CLOROBEN
Cloroben Corp., 115 Exchange Pl., Jersey City, N. J.

COAL & ASH HANDLING MACHINERY
(See Ash & Coal Handling Machinery)

COATINGS, ACID & ALKALI-PROOF
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 5, N. J.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.
Presstite Eng. Co., 3918 Chouteau Ave., St. Louis, Mo.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corporation, Etc.)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo, Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Av., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

COLLECTORS (Sludge)
(See Sludge Collectors)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York 18, N.Y.

COMMINUTORS
(See Grinders also)
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS, COLOR
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson, Baltimore 4, Md.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Presstite Eng. Co., 3918 Chouteau Ave., St. Louis, Mo.
Robinson Clay Product Co., 65 W. State St., Akron, Ohio.

COMPRESSORS, AIR
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton 2, N. J.
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS
Homelite Corp., Riverdale Ave., Port Chester, N. Y.

CONCRETE HARDENER
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.

CONCRETE MIXERS
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, Ohio.

CONCRETE PIPE
Lock-Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CONDENSERS (Steam)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

CONTRACTORS (Water & Sewage Works)
Cement Gun Co., P. O. Box 424, Allentown, Pa.
Layne & Bowler, Inc., Box 215, Hollywood Sta., Memphis 8, Tenn.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Term. Annex, Los Angeles, Calif.

CONVEYORS AND CONVEYING EQUIPMENT
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Div., 9 Codding St., Providence, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.

COPPERAS (Sulfate of Iron)
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULFATE
General Chemical Co., 40 Rector St., New York 6, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

COPPER TUBE
American Brass Co., Waterbury, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Federal Telephone and Radio Co., Newark 1, N. J.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wallace & Tiernan, Belleville 9, N. J.

COUPLINGS & CONNECTIONS, PIPE
James P. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

COUPLINGS, FLEXIBLE
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 4, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Warren Fdry. & Pipe Corp., 11 Broadway, New York, N. Y.

CULVERT CLEANERS
W. H. Stewart, 1051 So. Clinton St., Syracuse, N. Y.

CULVERT PIPE
(See Pipe, Culvert)

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Lee Hydraulic Co., Troy, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

CURB STOPS
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

DECHLORINATING EQUIPMENT AND CHEMICALS
American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

DE-MINERALIZATION (Water)
Amer. Water Softener Co., Philadelphia 33, Pa.
Chem. Equipment Co., P. O. Box 3098, Term. Annex, Los Angelcs 54, Calif.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIATOMITE FILTER SEPTUMS
Carborundum Co., Refractories Div., Perth Amboy, N. J.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES & TUBES
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equipment, Inc., 518 Hankes Ave., Aurora, Ill.

DIGESTER EQUIPMENT (Sludge)
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.

Dorr Co., 570 Lexington Ave., New York 22, N.Y.
Hardinge Co., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Sewage Filter)

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Dorr Co., 570 Lexington Ave., New York 22, N.Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DRAINS, GUTTER, FLOOR

James B. Clow Co., 201 N. Talman St., Chicago 80, Ill.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.

DRILLING & BORING EQUIPMENT

Bucyrus-Erie Co., South Milwaukee, Wis.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

DRIVES, CHAIN

(See Chains)

DRIVES, RIGHT ANGLE GEAR

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Payne Dean Co., Madison, Conn.

DRIVES, V-BELT

Allis-Chalmers Mfg. Co., 1192 So. 70th St., Milwaukee, Wis.

DRY CHEMICAL FEEDERS

(See Chemical Feeding Equipment)

DRYERS, ROTARY

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Link-Belt Co., 2045 Hunting Park Ave., Philadelphia 40, Pa.

DRYING SYSTEMS (Sludge)

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Gen. Amer. Transp. Co., 10 E. 49th St., New York 17, N. Y.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engr. & Res. Corp., 60 Wall Tower, New York, N. Y.

EARTH BORING TOOLS

Hydrauger Corp., Ltd., 681 Market St., San Francisco 5, Calif.

EARTH MOVING EQUIPMENT

Bucyrus-Erie Co., South Milwaukee, Wis.
Frank G. Hough Co., 752 Sunnyside Ave., Libertyville, Ill.

EJECTORS, PNEUMATIC or STEAM (For Sewage and Sludge)

Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
H. D. Fowler Co., Inc., 901 Lane St., Seattle, Wash.
Posey Iron Works, Inc., 560 So. Prince St., Lancaster, Pa.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICAL CONTROL EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Corp., Schenectady, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ELECTRICALLY OPERATED GATE VALVES

(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT

(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNIT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y. (Gasoline Engine Driven and Portable)
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ENGINES, DIESEL

Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

ENGINES, DUAL FUEL

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.

ENGINES (Gas & Gasoline)

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

ENGINES, SLUDGE GAS

Allis Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.

EXPANSION JOINTS—PIPE

(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR

(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATING

Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

FEED, CHEMICAL

(See Chemical Feeding Equipment)

FEED WATER FILTERS

Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

FEED WATER HEATERS

Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.

FERRIC CHLORIDE

Jordan Co., 51st St. & Merrimac Ave., Chicago, Ill.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa. (Liquid)

FERRIC CHLORIDE FEEDERS

(See Chemical Feed and Proportioning Equipment)

FERRIC SULFATE

Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

FIBRE PIPE

(See Pipe, Fibre)

FILTER ALUM

General Chemical Co., 40 Rector St., New York 6, N. Y.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTERING EQUIPMENT

American Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip. Co., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

FILTER PLATES AND TUBES

Carborundum Co., Refractories Div., Perth Amboy, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.

FILTER RATE CONTROLLERS & GAGES

(See Rate Controllers.)

FILTER SAND & GRAVEL

Infilco, Inc., 325 W. 25th Place, Chicago, Ill
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER UNDERDRAINS, SEWAGE

Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.

FILTER UNDERDRAINS, WATER

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL

Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.

FITTINGS, PIPE, SOLDER TYPE

American Brass Co., Waterbury, Conn.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Hays Mfg. Co., Erie, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Warren Fdry & Pipe Corp., 11 Broadway, New York, N. Y.
R. D. Wood Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

FITTINGS, TEES, ELLS, ETC.

Albert Pipe Supply Co., Inc., Berry and N. 13th St., Brooklyn 11, N. Y.
American Cast Iron Pipe Co., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

FLASH MIXING EQUIPMENT

(See Mixers & Mixing Equipment)

FLEXIBLE JOINTS

(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)

Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

FLOC PRODUCERS

Alhydro, Inc., 516 N. Charles St. Baltimore 1, Md.

FLOCCULATING EQUIPMENT

Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Iowa Valve Co., Oskaloosa, Iowa.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

FLOW METERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277, Term. Annex, Los Angeles, Calif.

FLOW RECORDERS

(See Rate of Flow Recorders)

FLOW REGULATORS

(See Rate of Flow Controllers)

FLOW TUBES

Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.

FLUMES, IRON & STEEL

R. D. Cole Mfg. Co., Newnan, Ga.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FOOT VALVE WITH STRAINER

(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS

L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.

Atlas Mineral Products Co., Mertztown, Pa.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

GAGES (Liquid Level, Pressure Recording)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.

GARBAGE GRINDERS

(See Grinders)

GAS DIFFUSERS

Carborundum Co., Refractories Div., Perth Amboy, N. J.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

GAS ENGINES

(See Engines, Gas & Gasoline)

GAS HOLDERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Bridge & Iron Company, 332 S. Michigan Ave., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

GAS INDICATORS AND DETECTORS

Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.

GATES, SHEAR

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Iowa Valve Co., Oskaloosa, Iowa.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.

GATES, SLUICE

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Filer and Stowell Co., Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Iowa.
S. Morgan Smith Co., York, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

GATE VALVE OPERATOR

Darling Valve and Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Payne Dean & Co., Madison, Conn.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GATE VALVES

(See Valves, Gate)

GEARS, SPEED REDUCING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

GENERATORS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

GENERATOR SETS, GAS & DIESEL ENGINES

(See Engine Generating Units)

GOOSENECKS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GREASE INTERCEPTORS

Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.

GREEN SAND (Zeolite)

Amer. Water Softener Co., Philadelphia 33, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N.Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar, New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City 22.
General Electric Co. (household), Bridgeport, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Westinghouse Elect. Corp. (household), Pittsburgh, Pa.

GRIT CHAMBER EQUIPMENT & GRIT WASHERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Dorr Co., 570 Lexington Ave., New York City 22.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

GROUND KEY STOPS

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

GUNITING CONTRACTING

Cement Gun Co., P. O. Box 424, Allentown, Pa.

HEATERS, DIGESTER

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip. Co., 518 Hankes Ave., Aurora, Ill.

HOSE, STEAM, AIR, WATER, SUCTION

American Brass Co., Waterbury, Conn.

HYDRANT PUMPS

(See Pumps, Hydrant)

HYDRANTS (Fire)

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Iowa.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., Inc., Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES

(See Valves, Gate)

HYDROGEN ION EQUIPMENT

(See pH Test Equipment)

HYPO-CHLORINATORS

American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Belleville 9, N. J.

HYPOCHLORITES (High Test)

(See Calcium Hypochlorite)

INCINERATORS

Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED

Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277, Term. Annex, Los Angeles, Calif.

INSERTING SLEEVES, VALVE

A. P. Smith, 545 N. Arlington Ave., East Orange, N. J.

INSTRUMENTS (Meteorological)

Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
M. C. Stewart, Ashburnham, Mass.
Wallace & Tiernan, Belleville 9, N. J.

INSULATION

Johns-Manville, 22 E. 40th St., New York City.
National Gypsum Co., Buffalo, N. Y.
Presstite Eng. Co., 3918 Chouteau Ave., St. Louis, Mo.

IRON SULFATE

(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS

Atlas Mineral Prod. Co., Mertztown, Pa.

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Presstite Eng. Co., 3918 Choutenu Ave., St. Louis, Mo.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.

JOINTS, EXPANSION—PIPE

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N .J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, MECHANICAL, FLEXIBLE

Amer. Brass Co., Waterbury, Conn.
Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.

LABORATORY APPARATUS AND REAGENTS

Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
LaMotte Chem. Co., Towson 4, Md.
Nat'l Technical Labs., Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

LEAD, CAULKING

Colonial Smelting & Ref. Co., Inc., Columbia, Penna.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS

(See Water Leak Locating Instruments)

LIGHTING

General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

LIMES

National Gypsum Co., Buffalo, N. Y.

LIQUID CHLORINE

(See Chlorine, Liquid)

LOCATORS, BOX, PIPE AND VALVE

Fischer Research Lab., Inc., 1961 University Ave., Palo Alto, Calif.
Goldak Co., 1543 W. Glenoaks Blvd., Glendale 1, Calif.

MANHOLE FRAMES, COVERS

James B. Clow Co., 201 N. Talman St., Chicago 80, Ill.
Warren Fdry. & Pipe Corp., 11 Broadway, New York, N. Y.

MANOMETERS

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oskaloosa, Iowa.
Meter Specialty Co., 1332 N. 7th St., Memphis, Tenn.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

METER COUPLINGS & YOKES

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Badger Meter Mfg. Co., 2357-71 N. 30th St., Milwaukee 10, Wis.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

METER REPAIR PARTS

Meter Specialty Co., 1332 N. Seventh St., Memphis, Tenn.

METERS, ELECTRIC

General Electric Co., Schenectady, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

METERS, FLOW TUBE

Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.

METERS, GAS

Fischer & Porter Co., Hatboro, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.

METERS, HYDRAULIC TURBINES

Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METER TESTING EQUIPMENT

Badger Meter Mfg. Co., 2357-71 N. 30th St., Milwaukee 10, Wis.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Ford Meter Box Co., Wabash, Ind.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, VENTURI

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METERS, WATER & SEWAGE

Badger Meter Mfg. Co., 2357-71 N. 30th St., Milwaukee 10, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Buffalo Meter Co., 2909 Main St., Buffalo, N. Y.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Meter Specialty Co., 1332 N. Seventh St., Memphis, Tenn.
Neptune Meter Co., 50 W. 50th St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, CLEANING SOLUTION

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders-Providence, Inc., Providence 1, R. I.
Skasol Corp., Webster Groves, Mo.

MIXERS AND MIXING EQUIPMENT

(Chemical, Water and Sewage)

Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25th Pl. Chicago 16, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

MOTORS, ELECTRIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

NIPPLES, PIPE

A. M. Byers Co., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Mfg. Co. Div., Bradford, Pa.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

NOZZLES, FLOW

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif

NOZZLES, SPRAY

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

OPERATING TABLES (Filter)

Amer. Water Softener Co., Philadelphia 33, Pa.
Builders-Providence, Inc., Providence 1, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

ORIFICES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PACKING

Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

PAINT, ACID RESISTING

Atlas Mineral Prod. Co., Mertztown, Pa.
Inertol Co., Newark 5, N. J.
Presstite Engr. Co., 3918 Chouteau Ave., St. Louis, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PENSTOCKS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wisc.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Posey Iron Works, Inc., 560 S. Prince St., Lancaster, Pa.

pH TEST EQUIPMENT

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
LaMotte Chem. Co., Towson 4, Balto, Md.
The Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Photovolt Corp., 95 Madison Ave., New York 16, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

PHOTOELECTRIC COLORIMETERS

Photovolt Corp., 95 Madison Ave., New York, N. Y.

PIPE & FITTINGS, SARAN, ETC.

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

PIPE AND TANK COATINGS

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT

Johns-Manville Co., 22 E. 40th St., New York City.

PIPE BENDING MACHINES

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hays Mfg. Co., Erie, Pa.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N.Y.

PIPE, CAST IRON

Albert Pipe Supply Co., Berry and N. 13th St., Brooklyn 11, N. Y.
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 386 4th Ave., New York City.
James B. Clow Co., 201 N. Tallman St., Chicago 80, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
McWane Cast Iron Pipe Co., P.O. Box 2601, Birmingham, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

PIPE, CEMENT LINED

American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

PIPE, CEMENT LINING OF

Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, CONCRETE, PRESSURE

Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
The Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, COPPER, BRASS AND BRONZE

American Brass Co., Waterbury, Conn.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE, CULVERT

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, New York.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago, Ill.
Robinson Clay Product Co., 65 W. State St., Akron, Ohio.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

PIPE CUTTING MACHINES

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N.Y.
Ridge Tool Co., Elyria, Ohio.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

PIPE DRILLS

Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N.Y.

PIPE ENAMELS, PROTECTIVE—COAL TAR

Inertol Co., Newark 5, N. J.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Presstite Engr. Co., 3918 Chouteau Ave., St. Louis, Mo.

PIPE FITTINGS (See Fittings)

PIPE, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N.Y.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.

PIPE JOINT COMPOUNDS

(See Jointing Compounds.)

PIPE JOINTS (Mechanical)

Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.

PIPE JOINT TOOLS

Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

PIPE LOCATORS

Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle Wash.
Globe Phone Mfg. Co., Reading, Mass.
Goldak Co., 1543 W. Glenoaks Blvd., Glendale 1, Calif.

PIPE, SEWER

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., 100 N. La Salle St., Chicago, Ill.
Preload Corp., 211 E. 37th St., New York 16, New York.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL (All Types)

R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Posey Iron Works, Inc., 560 S. Prince St., Lancaster, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE TAPPING MACHINES

Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

PIPE TEST PLUGS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
Richmond Fdry. & Mfg. Co., P. O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N.Y.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.

PIPE, VITRIFIED CLAY

(See Vitrified Clay Pipe and Products.)

PIPE, WROUGHT IRON

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 N. Exchange St., Providence 1, R. I.
Posey Iron Works, Inc., 560 S. Prince St., Lancaster, Pa.
Sonken-Galamba, 2nd & Riverview, Kansas City 18, Kan.

PITOT TUBES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT

Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

POROUS TUBES AND PLATES

Carborundum Co., Refractories Divn., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PRESTRESSED CONCRETE TANKS

Preload Corp., 211 E. 37th St., New York 16, N. Y.

PRESSURE REGULATORS

(See Regulators, Pressure)

PROPORTIONING EQUIPMENT

(See Chemical Feed and Proportioning Equip.)

PUMPING CONTROLS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.

PUMP PRIMERS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

PUMPS, ACID-HANDLING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Peerless Pump Div. Food Machinery and Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

PUMPS, CELLAR DRAINER

(See Pumps, Sump)

PUMPS, CENTRIFUGAL

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PUMPS, DIAPHRAGM

Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., 570 Lexington Ave., New York City 22.
Edson Corp., 49 D. St., South Boston, Mass.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Marlow Pumps, Inc., 412 Greenwood Ave., Ridgewood, N. J.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HYDRANT

Edson Corp., 49 D St., South Boston, Mass.

PUMPS, HYDRAULIC

De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Ross Valve Mfg. Co., Inc., Troy, N. Y.

PUMPS, JETTING

Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.

PUMPS, PORTABLE

Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwauke 4, Wis.

Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.

PUMPS, ROTARY

De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PUMPS, SELF PRIMING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Layne & Bowler, Inc., P. O. Box 215 Hollywood Sta., Memphis 8, Tenn.
Marlow Pumps, 412 Greenwood Ave., Ridgewood, N. J.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin St., Columbus 16, O.
Marlow Pumps, 412 Greenwood Ave., Ridgewood, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., 570 Lexington Ave., New York City 22.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Marlow Pumps, 412 Greenwood Ave., Ridgewood, N. J.
Walker Process Equip, Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP (AND CELLAR DRAINER)

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 West Avenue, 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, VACUUM

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Roots-Connersville Blower Corp., P O. Box 327, Connersville, Ind.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

RAIN GAGES

Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS

Ridge Tool Co., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE (Water and Gas)

American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Golden-Anderson Valve Spec., Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESIDUAL CHLORINE CONTROL APPARATUS

Builders-Providence, Inc., Providence 1, R. I.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Chemical Equipment Co., P. O. Box 3098, Term. Annex, Los Angeles 64, Calif.
Fischer & Porter Co., Hatboro, Pa.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Chem. Equip. Co., P. O. Box 3098 Term. Annex, Los Angeles 54, Calif.
Darling Valve & Mfg. Co., Williamsport, Pa.

RUBBER PACKING GASKETS

Northrop & Co., Spring Valley, N. Y.

RUST PREVENTION (Tanks, Pipe Lines, Submerged Metal)

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Electro Rust-Proofing Corp., 1026 Wayne Ave., Dayton 19, Ohio. (Cathodic Protection)
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Oakite Products, Inc., 73 Thames St., New York 6, N. Y.
Philadelphia Quartz Co., Ledger Bldg., 5th & Chestnut Sts., Philadelphia, Pa.
Presstite Engr. Co., 3918 Chouteau Ave., St. Louis, Mo.
Wallace & Tiernan, Belleville 9, N. J.

SADDLES, PIPE

Clow & Sons, James B., 201 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SAMPLERS AND SAMPLING TABLES

Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

SCALES, SLUDGE CONVEYOR

Builders-Providence, 9 Codding St., Providence, R. I.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace & Tiernan, Belleville 9, N. J.

SCREENINGS, DEWATERERS

Gen. Amer. Trans. Corp., 10 E. 49th St., New York 17, N. Y.

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, SAND, GRAVEL AND STONE

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City 22.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip. Co., 518 Hankes Ave., Aurora, Ill.

SCREENS, VIBRATING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, WATER WELL

Layne & Bowler, Inc., P.O. Box 215, Hollywood Sta., Memphis 8, Tenn.

SCUM REMOVERS

(See Clarifiers.)

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Nat'l Clay Pipe Mfrs. Inc., 100 N. LaSalle St., Chicago 2, Ill.

SEPTIC TANK CLEANERS

Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.

SEPTIC TANKS (Vitrified Clay)

Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.

SERVICE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

SERVICE PIPE

Amer. Brass Co., Waterbury, Conn.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SEWAGE SLUDGE INCINERATOR

Dorr Co., 570 Lexington Ave., New York City 22.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWER CLEANING EQUIP. AND SERVICE

Bucyrus-Erie Co., South Milwaukee, Wis.
J. C. Fitzgerald, P.O. Box 289, Coral Gables 34, Fla.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N.Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
W. H. Stewart, 1051 So. Clinton St., Syracuse, N.Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER ODOR PREVENTION
(See Chlorine.)

Cloroben Corp., Jersey City, N.J.
Pittsburgh Plate Glass Co., Columbia Chem. Div., Fifth Ave., at Bellefield, Pittsburgh 13, Pa.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

SEWER PIPE

(See Pipe, Sewer.)

SEWER PIPE JOINTS

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
L. A. Weston, Adams, Mass.

SEWER RODS

Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, 1051 So. Clinton St., Syracuse, N. Y.

SIPHONS (Sewage)

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N.J.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

SLEEVES, PIPE REPAIR

Clow & Sons, James B., 201 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N.Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Rensselaer Valve Co., Troy, N.Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

SLEEVES, TAPPING (Valve)

Eddy Valve Co., Waterford, N.Y.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Iowa Valve Co., Oskaloosa, Ia.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N.Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

SLUDGE COLLECTORS

American Well Works, 100 N. Broadway, Aurora, Ill
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 7349 Wolfram St., Chicago 18, Ill.
Dorr Co., 570 Lexington Ave., New York City 22.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS

Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS

(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Hardinge Corp., York, Pa.
Jeffrey Mfg. Co., 966 N. 4th St., Columbus 16, O.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip, Inc., 518 Hankes Ave., Aurora, Ill.

SLUDGE GAS ENGINES

(See Engines, Sludge Gas)

SLUDGE PUMPS

(See Pumps, Sludge)

SLUDGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.

SNUBBERS

(See Silencers.)

SODA ASH

Diamond Alkali Co., Pittsburgh, Pa.
Mathieson Chem. Corp., 60 East 42nd St., New York 17, N. Y.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM BISULPHITE

General Chemical Co., 40 Rector St., New York, N. Y.

SODIUM CHLORITE

Mathieson Chem. Corp., 60 East 42nd St., New York 17, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R.I.

SODIUM PHOSPHATES (Glassy)

Calgon, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 30, Pa.

SODIUM SILICATE

Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS

(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SPRINKLING FILTER EQUIP.

Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City 22, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS

(See Filter Underdrains, Sewage.)

STACKS

Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Posey Iron Works, Inc., 560 S. Prince St., Lancaster, Pa.

STANDPIPES

(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION

(See Cathodic Protection Process.)

STERILIZING WATER MAINS

(See Water Main Sterilization)

STIRRERS (Laboratory)

Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., 303 S. 6th St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

STOKERS

Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., Pittsburgh 30, Pa.

STORAGE TANKS

(See Standpipes and Tanks)

STRAINERS, SUCTION

Barrett, Haentjens & Co., Hazleton, Pa.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.

SULPHATE OF ALUMINA

(See Filter Alum)

SULPHUR DIOXIDE (Liquid)

Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

SUPERNATANT LIQUOR

(Selectors and Treaters)
Pacific Flush-Tank Co., 4141 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip, Inc., 518 Hankes Ave., Aurora, Ill.

SWITCHBOARD & SWITCH GEAR

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Mfg. Co., Pittsburgh 30, Pa.

TANK MAINTENANCE & REPAIR

Dixie Tank & Bridge Co., P. O. Box 14, Memphis 1, Tenn.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Speelmon Elevated Tank Service, 822 N. Court St., Rockford, Ill.

TANKS AND STANDPIPES (Steel)

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

TANKS, RUBBER LINED

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Posey Iron Works, Inc., 560 S. Prince St., Lancaster, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

TAPPING MACHINES

Glauber Brass Mfg. Co., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

TASTE & ODOR REMOVAL CHEMICALS

General Chemical Co., 40 Rector St., New York 6, N. Y.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Mathieson Chem. Corp., 60 E. 42nd St., New York 17, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

TESTERS (Water Meter)

Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

TEST PLUGS (for Pipe)

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Eddy Valve Co., Waterford, N. Y.
Glauber Brass Mfg. Co., Kinsman, Ohio.
Richmond Fdry. & Mfg. Co., P.O. Box 5150, Saunders Sta., Richmond, Va.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

THICKENERS (Sludge)

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip, Inc., 518 Hankes Ave., Aurora, Ill.

TOOL BOXES, PORTABLE
Littleford Bros., Inc., 453 E. Pearl St., Cincinnati 21, Ohio.

TOOLS, PIPE
(See Pipe Tools.)

TOOLS, PNEUMATIC
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.

TRACTORS, BULLDOZERS, Etc.
Bucyrus-Erie Co., South Milwaukee, Wis.
Frank G. Hough Co., 752 Sunnyside Ave., Libertyville, Ill.

TRANSFORMERS, ELECTRIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh, Pa.

TRAPS, DRIP, FLAME, SEDIMENT
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago 13,, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRENCHING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Frank G. Hough Co., 752 Sunnyside Ave., Libertyville, Ill.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

TRICKLING FILTER EQUIPMENT
Chain Belt Co., 1600 W .Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Yeomans Bros., 1423 N. Dayton St., Chicago 22, Ill.

TRICKLING FILTER UNDERDRAINS
(See Filter Underdrains)

TRITURATORS
(See also Grinders)
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.

TURBINES, HYDRAULIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1. Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

UNIT SUBSTATIONS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Chapman Valve Mfg., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oskaloosa, Ia.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVE BOX LOCATORS
Globe Phone Mfg. Corp., Reading, Mass.
Goldak Co., 1543 W. Glenoaks Blvd., Glendale 1, Calif.

VALVE INSERTING MACHINES
A. P. Smith Mfg. Co., 545 No. Arlington Ave., East Orange, N. J.

VALVE OPERATOR
(See Gate Valve Operator)

VALVES
American Car & Fdry. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N.J.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, AIR RELEASE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Golden, Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

VALVES, AIR & VACUUM
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc. 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Ia.
Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Rensselaer Valve Co., Troy, N.Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Valve and Primer Corp., 127 N. Dearborn St., Chicago, Ill.

VALVES, ALTITUDE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, BACKWATER
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.

VALVES, BUTTERFLY
Crane Co., 836 S. Mich. Ave., Chicago 5, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, CHECK
Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Oskaloosa, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
The Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, CHLORINE
Amer. Car and Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Wallace & Tiernan Co., Inc. Belleville 9, N. J.

VALVES, CONE
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, DIAPHRAGM
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, ELECTRICALLY OPERATED
(See Valves, Motor Operated.)

VALVES, EMERGENCY TRIP
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, FLAP
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Iowa Valve Co., Oskaloosa, Ia.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.

VALVES, FLOAT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., South Boston, Mass.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oskaloosa, Ia.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FOUR WAY
American Water Softener Co., Philadelphia 33, Pa.
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Ia.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, HARD RUBBER LINED
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

VALVES, HYDRAULIC CYLINDER OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

Stuart Corp. 516 N. Charles St., Baltimore 1, Md.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, LUBRICATED PLUG
American Car & Fdy Co., 30 Church St., New York 8, N. Y.
Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

VALVES, MOTOR OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-American Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

VALVES, MUD AND PLUG
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Infilco Inc., 325 W. 25th Pl. Chicago 16, Ill.
Iowa Valve Co., Oskaloosa, Ia.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, PRESSURE REDUCING
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Phila. 44, Pa.
S. Morgan Smith, York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RELIEF
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., N. Y. 20.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)
Barrett, Haentjens & Co., Hazleton, Pa.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.
A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

VARIABLE SPEED TRANSMISSIONS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

VENTURI TUBES
American Water Softener Co., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe, Cleveland 10, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

VIBRATING SCREENS (Liquid)
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VISES, PIPE
Ridge Tool Co., Elyria, Ohio.

VITRIFIED CLAY PIPE AND PRODUCTS
Nat'l Clay Pipe Mfrs., Inc., 100 N. La Salle St., Chicago 2, Ill.

WASTE GAS BURNERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS
(See Laboratory Apparatus and Reagent,)

WATER HAMMER ARRESTERS
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Ross Valve Mfg. Co., Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

WATER LEAK, LOCATING INSTRUMENTS
Fisher Research Lab. Inc., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Co., Reading, Mass.
Goldak Co., 1543 W. Glenoaks Blvd. Glendale 1, Calif.

WATER LEVEL CONTROL
Automatic Control Corp., 1005 University Ave., St. Paul 4, Minn.
Builders-Providence, Inc., Providence 1, R. I.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

WATER MAIN CLEANING
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp, 516 N. Charles St., Baltimore 1, Md.

WATER MAIN PACKING GASKETS
Northrop & Co., Spring Valley, N. Y.

WATER MAIN STERILIZATION (A Service)
Alan A. Wood
1649 N. Broad St.,
Philadelphia, Pa.
Pitts. Plate Glass Co., Columbia Chem. Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Inertol Co., Newark 5, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Presstite Engr. Co., 3918 Chouteau Ave., St. Louis, Mo.

WATER SOFTENING CHEMICALS AND COMPOUNDS
(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Amer. Water Softening Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Dorr Co., Inc., 570 Lexington Ave., New York City 22, N. Y.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER STABILIZATION (Chemicals for)
Calgon, Inc., 323 4th Ave., Pittsburgh 30, Pa.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.

WATER SUPPLY CONTRACTORS
(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION
Amer. Water Softener Co., Philadelphia 33, Pa.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Calgon, Inc., 323 4th Ave., Pittsburgh 30, Pa.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Oakite Products, Inc., 73 Thames St., New York 6, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER TREATMENT PLANTS (Steel)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Amer. Water Softener Co., Philadelphia 33, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

WEED KILLERS
Cloroben Corp., 15 Exchange Pl., Jersey 2, N. J.
C. B. Dolge Co., Westport, Conn.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.

WELLS, COMPLETE
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

WIND VANES AND INDICATORS
M. C. Stewart, Ashburnham, Mass.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET
Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.

WROUGHT IRON (Pipe, Gates, Bars, Etc.)
A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

ZEOLITE AND ZEOLITE SOFTENERS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Amer. Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

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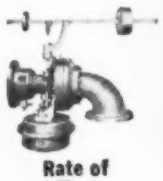
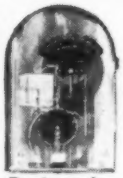
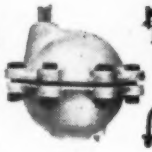
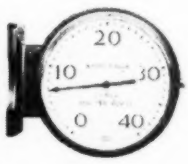

Rate of Flow Controllers

Circular Chart Type Meters

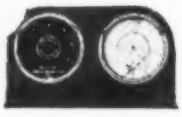

Rectangular Chart Type Meters


Air Release Valves

Pitot Recorders



Wash Water Gauges


Filter Gauges

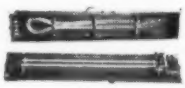
Orifice Plates

Fixed Manometers

Pitot Rods

Flow Nozzles

Air Inlet Valves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INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS

(Where to Find It)

By LINN H. ENSLOW
Editor, "Water & Sewage Works"

IT goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water and sewage works men is found in the manuals published by the American Water Works Association and the Federation of Sewage Works Associations.

Text books, manuals, hand-books, journals, and catalogs are named alphabetically in the attached list of recommended reference works for water and sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists called on to offer suggestions in making up a set of reference works.

LIST NO. 1—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Chlorine Manual (F)	The Chlorine Institute, New York 17, N.Y.	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Copper Sulphate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Elements of Water Supply Engineering (2nd Ed.)	John Wiley & Sons, New York City	Waterman
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Handbook of Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Lab. Manual—Water and Sewage Analysis, 3rd Ed. ($3.00)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co., Brooklyn 2, N. Y., c/o State Dept. H.	A. A. Hirsch
Manual for Water Works Operators ($3.00)	Texas Water and Sewage Works Assn., Austin, Tex.	Various
Manual of Recommended Water Sanitation Practice (15c)	U.S. Govt. Printing Office, Washington, D.C.	
Manual of Water Quality and Treatment (2d Ed.)	Am. Water Works Assn., New York City	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Modern pH Control (F)	W. A. Taylor Co., Baltimore, Md.	
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracy
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Public Water Supplies—4th Ed. ($6.00)	John Wiley & Sons, New York City	Turneaure & Russell
Standard Methods of Water Analysis, 9th Ed. ($4.00)	A. P. H. A. and A. W. W. A., New York City	Various
Taste and Odor Control in Water Purification (F)	Industrial Chem. Sales Div., New York 17, N. Y.	
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Water Purification Control, 3rd Edition	Williams & Wilkins, Baltimore, Md.	Hopkins
Water Purification for Plant Operators ($2.50)	McGraw Hill Co., New York City	Norcom and Brown
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Treatment and Purification 2nd Ed. ($2.75)	McGraw Hill Co., New York City	Ryan
Water Works Engineering in Disaster (F)	O.C.D. Pub. No. 2022, Washington, D. C.	McCallum
Water Works Handbook ($7.00)	McGraw Hill Co., New York City	Flynn, Weston & Bogert
Water Supply & Treatment, 3rd Ed. ($0.75)	National Lime Assn., Washington, D. C.	Hoover

(F) Available as Free Publication at this writing.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Applied Hydraulics ($6.50)	John Wiley & Sons, Inc., New York City	Addison
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Data Book on Design for Civil Engineers (3 Vols.)	John Wiley & Sons, Inc., New York City	Elwyn E. Seelye

(*Continued on page* R-14)

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS
(In addition to List No. 1)

Books	*Publishers*	*Authors*
Deep Well Drilling	The Gulf Publishing Co., Houston, Tex.	Walter H. Jeffery
Design of Dams ($5.00)	McGraw-Hill Book Co., New York City	Hanna and Kennedy
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Geomorphology	McGraw-Hill Book Co., Inc., New York City	A. K. Lobeck
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman
Ground Water, Its Development, Uses & Conservation	Edward E. Johnson, Inc., St. Paul, Minn.	Bennison
Guiding Principles of Public Service Reg. (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Handbook of Applied Hydraulics ($7.50)	McGraw-Hill Co., New York City	Davis
Hydraulics 5th Ed. ($4.00)	McGraw-Hill Co., New York City	King
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
Laboratory Control of Water Purification ($4.00)	Case, Sheppard, Mann Pub. Co., New York 18, N. Y.	Cox
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
pH and Its Practical Application ($3.50)	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Physics of the Earth IX	McGraw-Hill Book Co., Inc., New York City	Oscar E. Meinzer
Plumbing Engineering ($3.50)	Pittman Publishing Co., New York	Cleverdon
Pocket Companion (nominal)	Carnegie-Steel Corp., New York City	
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Pump Handbook	National Press, Millbrae, Calif.	Finch
Standards of Hydraulic Institute—8th Ed. ($3.00)	Hydraulic Institute, New York 6, N. Y.	
Standard Practices for Stationary Diesel Engines ($2.50)	Diesel Engine Mfg. Assn., Chicago, Ill.	
Summary of Census Data on Water Treatment Plants in the United States	Am. Water Works Assn. Reprint	U. S. Pub. Health Service
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
The Hardy Cross Method of Distribution System Design	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
The Quest for Pure Water ($5.00)	Amer. Water Wks. Assn., New York 18, N. Y.	Baker
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Water Bacteriology—6th Ed. ($4.50)	John Wiley & Sons, New York 16, N. Y.	Prescott, Winslow & McCrady
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Water Supply Paper No. 658 (Quality of Waters)	U. S. Geological Survey, Washington, D. C.	Stabler

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Chlorination in Sewage Treatment****	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chlorine Manual (F)	The Chlorine Institute, New York 17, N. Y.	
Lab. Manual of Water and Sewage Anal. 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Manual for Sewage Plant Operators ($3.50)	Texas Water & Sewage Wks. Assn., c/o State Dept. of Health	
Manual of Sewage Works Operation****	New Jersey Sewage Expt. Sta., New Brunswick, N. J.****	
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Principles of Sewage Treatment ($0.50)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Sewage Sludge Utilization as Fertilizer (F. S. W. A. Man. No. 2) ($1.25)	Fed. Sew. Wks. Assns., Champaign, Ill.	
Sewage Treatment ($3.00)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Stand. Meth. of Water and Sewage Analysis, 9th Ed. ($4.00)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.

***Note*—Sewage works men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books.

LIST NO. 4—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**
(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge
Modern Sewage Disposal ($3.50)****	Federation of Sewage Works Assns., New York City	Various
Municipal and Rural Sanitation, 3rd Ed.	McGraw-Hill Book Co., Inc., New York City	Ehlers & Steel
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Sewage Trade Waste Treatment	Govt. Printer, Adelaide, Australia	Henry J. N. Hodgson
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewerage and Sewage Treatment—2nd Ed. ($4.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage and Sewage Treatment—6th Ed. ($6.50)	John Wiley & Sons, New York City	Babbitt
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Stream Sanitation ($3.25)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	

(F) Available as Free Publication at this writing.
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For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4" to 30" are guaranteed for services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

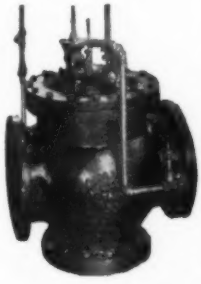
Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Intaliled in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller



Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

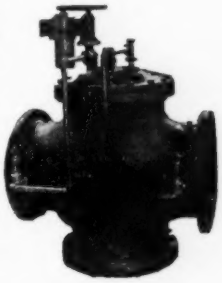
Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.



Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½" hose connections delivering independently from shutoff to full pressure and a fifth connection 2½" to 3" delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Line: Internal Packing Replaced Through Top of Valves.

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: **Burlington, New Jersey**

SALES OFFICES

Philadelphia, Birmingham, San Francisco, Pittsburgh, Cleveland, Minneapolis, Seattle, New York, Chicago, Boston, Kansas City, Dallas, Houston, Los Angeles

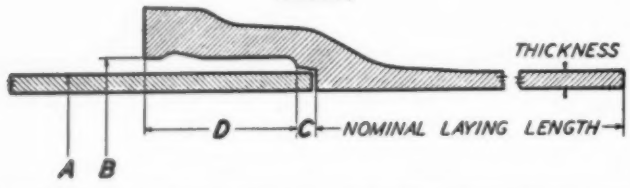
Makers of

SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
PIT CAST IRON PIPE AND FITTINGS
U. S. STANDARDIZED MECHANICAL JOINT PIPE
THREADED PIPE IN IRON PIPE SIZES
WEBRE INDUSTRIAL AND SUGAR APPARATUS
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CAST IRON ROOF
USICAST CHEMICAL CASTINGS

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE 1



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	150	12.7	225	12.4
3	250	.36	165	13.7	240	13.4
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

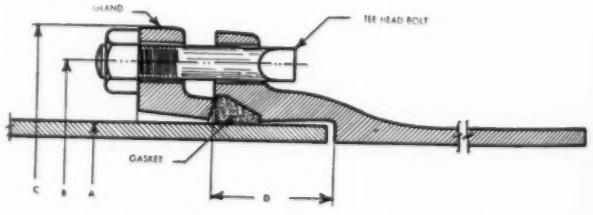
THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.32	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

U. S. STANDARDIZED MECHANICAL JOINT



We are now prepared to furnish U. S. Standardized Mechanical Joint Pipe and Fittings in sizes from 3" to 24" with parts that are interchangeable with those furnished by other manufacturers of cast iron mechanical joint pipe.

FINANCING DISTRIBUTION SYSTEM EXTENSIONS*

by
ALFRED O. NORRIS

Vice-Pres. and Gen. Mgr. Birmingham Water Works Co., Birmingham, Ala.

MANY methods and practices followed in the extension of distribution systems into new territory, many of which are not producing the income they should, require review and careful analysis to determine whether or not they are properly financed. It is quite conceivable that many extensions, although bringing in additional revenue, are, in fact, a financial burden on the system as a whole. Of course, some of the past methods cannot be changed overnight, as they are so securely fixed by custom, ordinance, or contract.

Equitable Rate Structure a Major Consideration

In considering this subject, there is one major factor to keep in mind—the rate structure or schedule. Almost every water works operator, whether his plant is publicly or privately owned, will find it most distasteful and difficult to revise the rate schedule of his property unless he is able to make the revision downward. It will be assumed, therefore, that it is the desire, and should be the responsibility, of every operator to approach the expansion of the water works system with an eye toward the preservation of the existing charges for water service. Precaution should also be taken to prevent the necessity of increasing the rates charged existing customers to help defray the costs of taking on new customers supplied by main extensions not properly financed.

Two factors must be considered in the proper financing of an extension: first, the revenue of the particular extension and the increase in operating expenses it will cause; and second, the additions to plant and property—such as services and meters—as well as the investment in pumps, filters, reservoirs and the like, that will be required to supply adequately the extension and the consumers taking water from it.

Calculating Probable Revenue

The calculation of the probable revenue from an extension can be approached from several angles. Rather than estimating the total revenue an extension may produce and working out the financing from this point, it is better and safer to eliminate as much guesswork as possible. There never is the certainty that all the lots will be built upon and, if built upon, that the units will be occupied. To reduce these uncertainties to a minimum, it is, therefore, best to work out the problem by giving consideration to the additional revenue as water customers become attached to the mains.

From the general character of the development and its location, as well as the size and design of the units, it is not too difficult to arrive at an average estimated revenue to be expected from each unit to be served by the extension. Such an estimate is, of course, based on the revenues being received from similar units already attached to the system.

The probable operating expenses of an extension—or rather the increase in the operating expenses of the property as a whole due to the addition of the new customers—cannot be properly approached by any method other than average costs. It would require an exhaustive study to find out by what increment each new customer would increase operating expenses, and if this increment were to be determined for each new customer it would naturally have to vary. Such an approach would also make it necessary to determine just which new customer required the hiring of an additional employee in the water works organization. As the development of this paper will show, the economies of an extension can be properly treated only on an overall basis and with a long-term view.

Average costs can best be expressed by giving consideration and weight to the operating ratio, the percentage of the gross operating earnings expended for operation and maintenance. Deducting this figure from the gross operating earnings gives the return—that is the amount available to meet the costs of borrowed capital and to provide a profit. Operating ratios are not the same for all properties as each has its own particular problem, affecting in one way or another the relationship between revenues and expenses. The operating ratio of a single property will, however, remain fairly constant from year to year, moving in one direction or the other rather slowly. To determine the operating ratio of a property for use in calculating the earnings of an extension, it would be well to figure it out for a number of years in order to eliminate any years during which some unusual event occurred and materially disturbed the operating ratio for that year.

Example

To take an example, it may be assumed that the estimated gross revenues from the extension under consideration average $15.00 a unit and that the operating ratio of the water works property which is making the extension is 40 per cent. The return from each unit, disregarding other matters, will, therefore, be $15.00 minus $6.00 (40 per cent of 15), which leaves $9.00. This $9.00 is the amount of money that will be available from each unit to support the investment in the pipelines, service lines, meters and other materials making up the extension as well as other additions to the plant as a whole.

Investment Required in Other Facilities

It is at this point that the greatest tendency exists for making errors and omissions in the proper financing of distribution system extensions. Small properties which have no prospects of further growth and at the same time have ample supply facilities can assume that a reasonable return on the investment in the extension alone is sufficient. Should it develop, however, that the property needed some expansion of its supply, the earnings of the property under existing rates would not be sufficient to support an investment in additional supply facilities, which, by their very nature, are not revenue producers. In determining the proper financing arrangement for distribution system extensions, consideration must also be given to the required investment in other plant facilities.

Admittedly, additional investments in plant facilities, other than pipelines, are not in the same category as the investments made in pipelines. Plant facilities are added in larger steps and at uneven rates. In a property's history there will be times when the supply facilities are more than adequate and times when they should be enlarged.

However, assuming that the development of plant facilities has been kept reasonably abreast of the growth of the distribution system, and records have been accurately maintained, the ratio of the total cost of, or investment in, pipelines alone to the total investment will provide a very useful figure in determining what the proper return on a pipeline extension should be. This ratio is arrived at by dividing the total cost or investment in pipelines, fire hydrants and fire hydrant branches by the total plant value. The figure should not vary much from year to year in the future, as it is based on total values over a long period and yearly variations will be small by comparison.

Apportioning the Investment

Assuming that the investment in pipelines alone of the water works property mentioned above is 45 per cent of the total value of the plant, for every $45 invested in pipelines another $55 will eventually have to be expended for all other facilities needed to render service to customers on the extension under consideration. Put in another way, this means that, at the particular imaginary plant, for every $1.00 invested in water mains, fire hydrants and hydrant branches $1.22 will have to be spent on other facilities.

It was found previously that of the $15.00 of estimated revenue for each unit, $6.00 would be spent on operating expenses, leaving $9.00 available to support the investment in the facilities needed to supply each unit. For the purposes of this paper, a return of 6 per cent on the value of the property will be assumed sufficient to cover the overall costs of borrowed money and a reasonable profit. The $9.00 using the figure of 6 per cent will therefore support an investment of $150. This $150, unfortunately, is not the amount of money that can be prudently spent on pipelines for each of the $15.00 customers expected on the extension under consideration. To take care of the cost of other facilities to supply each of these new customers, only 45 per cent of the $150, or $67.50, can be invested in water mains. The remainder, $82.50, will have to be spent on other facilities, such as meters, services, pumps and filters, if the existing relationship of the cost of mains to the total value of property holds true.

If the need for investment in all possible facilities other than mains is neglected when arriving at the return an extension should yield, it will become necessary to increase water rates at some future time. If all the revenue available from an extension is used to support the investment in pipelines alone, there will not be any cushion of revenue to support the investment in other needed facilities, such as added filter and pumping capacity. Furthermore, should it be found necessary to increase rates to support the cost of added facilities because of such omission, the increased rates would be imposed on the old customers for whom the additional facilities were not needed, as well as on the new customers.

Calculating Return Necessary

With an operating ratio of 40 per cent, a figure of 45 per cent representing the ratio of the value of pipelines to the total value

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of the plant and 6 per cent as a fair return, $15.00 of revenue could support an investment of $67.50 in pipelines. This represents a gross return of 22.2 per cent, calculated by dividing $67.50 into $15.00. The dollar figures can be eliminated and, using only the three percentages, the same 22.2 per cent can be arrived at thus:

$$\frac{0.06}{0.60 \times 0.45} = \frac{1}{4.5} = 0.222 = 22.2\%$$

The 22.2 per cent figure means that a water works property operating under the above conditions must earn 22.2 per cent of the cost of a pipeline extension to pay the increased operating expenses and receive a return of 6 per cent on the cost of the extension and the cost of other necessary additions to its supply facilities used in rendering service to the extension customers.

As mentioned before, probably no two water works properties have exactly the same operating ratio or relationship between the total value of pipe and the total value of plant. However, assuming that records have been kept so that it is possible to determine what these two percentage figures are, and that the desired return has been established, the same calculations as above can be made to determine what the gross yield on a pipeline extension should be, expressed as a percentage of the cost of the extension.

Assuring the Proper Return

When it is apparent that a pipeline extension will not yield the desired gross return on the cost of pipeline installation alone, it is quite essential that some arrangement be agreed on so that the water property will be assured of the proper return.

One way would be to work out with the developer, or a representative of the customers to be served by the extension, an agreement by which the water property would be guaranteed the required return (22 per cent in the example used). The water utility would then keep an account of the revenue collected on the extension each year and calculate what percentage of the cost of the extension this revenue represented. The guarantor would then make up the difference between the percentage found and the guaranteed amount, until such time as the actual annual revenue collected equalled or exceeded the required amount.

This type of contract does not have much appeal to a developer or an individual, because of its continuing nature. Furthermore, it would not be of much value to the utility unless the credit of the guarantor were well established. The most satisfactory arrangement from the utility's point of view, and also from the developer's, is to have the entire cost of the pipeline extension placed on deposit with the utility. The utility then has the money and the developer has some definite figure to work with for the determination of his costs of development.

Since the utility can calculate what its gross return on an extension should be, it ought to be willing to refund to the depositor sums of money which would be representative of the amount the utility can afford to invest for the revenue produced by the new customers added to the extension. Using the same gross return of 22.2 per cent and the estimated revenue of $15.00 previously assumed for each unit on the extension, the utility can afford to refund, for each unit added to the extension, a sum equivalent to $15.00 divided by the desired gross return of 22.2 per cent, or $67.50. This should be recognized as the same figure previously arrived at.

Expressed in another way, using the reciprocal of 0.222 which is 4.5, and multiplying: $4.5 \times \$15.00 = \$67.50$. This reciprocal can be used to express briefly what the utility can invest in pipeline extensions; namely, 4½ times the estimated revenue.

This factor of 4½ would not hold true for all properties, but a similar figure can be developed for any given utility.

PIPE FLOW CHART

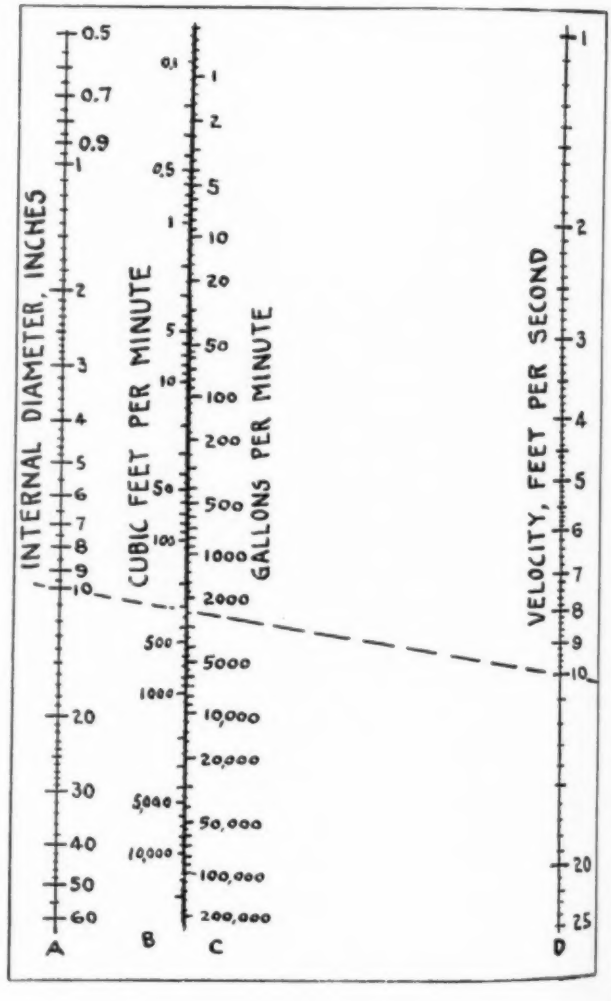
By simply laying a straightedge across this chart any one of these questions may be answered:

1. How many cubic feet will flow through a pipe of given diameter at a given velocity?
2. How many gallons, other conditions being the same as in No. 1.
3. What will be the velocity in feet per second, knowing the diameter and cubic feet per minute?
4. Same as (3) except that the flow is given in ga lons per minute.
5. What diameter of pipe must be used to carry a given number of cubic feet per minute at a given velocity?
6. Same as (5) except that quantity is in gallons per minute.

For example, how many gallons of water per minute will flow from a 10 inch pipe line if the velocity reaches 10 ft. per second?

The dotted line drawn across the chart shows that if the internal diameter of the pipe is 10 inches (col. A), and the water is flowing at a velocity of 10 ft. per second (col. D), the amount of water flowing is a hair less than 2,500 gal. per minute (col. C), which is equivalent to about 325 cubic feet per minute (col. B).

Naturally the chart may be used to obtain the pipe diameter needed to avoid exceeding a given velocity at a given rate of flow. It may also be used for converting gallons to cubic feet and the reverse.



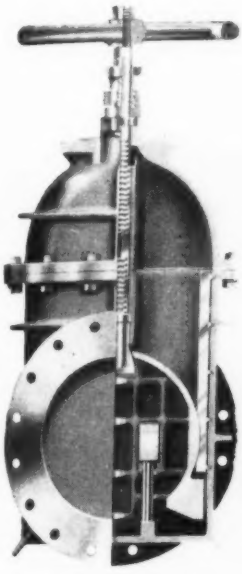
Contributed by W. F. Schaphorst, M.E., Newark, N. J.

M & H VALVE AND FITTINGS COMPANY

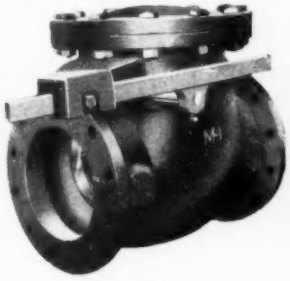
ANNISTON, ALABAMA

Write for Catalog 34 showing other M & H products for water works or sewage plants.

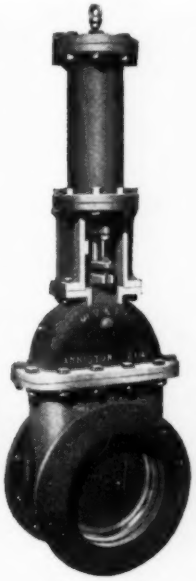
The Mark of Quality



Square bottom Gate Valve

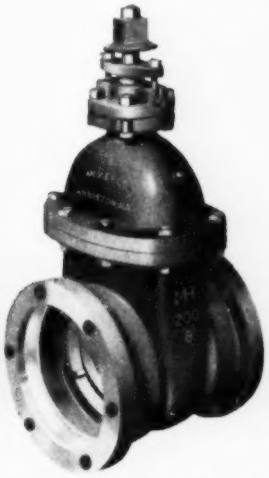


Lever-weighted Swing Check Valve



Hydraulic Gate Valve

Hub-end A.W.W.A. Gate Valve



Mechanical Joint A.W.W.A. Gate Valve

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.

M & H Square Bottom Gate Valves: specially designed for operation in any position. Particularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.

Flanged-end A.W.W.A. Hydrant

PRESSURE CLASSIFICATION 2" TO 30" SIZES

Class	Working Pressure	Hydrostatic Test
AA	0– 25 lb.	50 lb.
A	26– 50 lb.	100 lb.
B	51–100 lb.	200 lb.
C	101–200 lb.	350 lb.

A.W.W.A. Type Hydrant with mechanical joint.

M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple, rugged design minimizes maintenance costs. Features are:

1. Dry Top —Operating threads protected from action of water. No rust, corrosion or freezing.
2. Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.
3. Revolving Head, outlets faced in any direction.
4. Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.
5. Lengthening of Hydrant without digging up or requiring complete new barrel.
6. Double Lead Gaskets on Bronze valve seat.
7. Removal of Bronze Seat, or any working part, without digging up Hydrant.
8. Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.
9. Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.
10. Compression Type. Water pressure keeps valve tight.

Johns-Manville answers 13 QUESTIONS frequently asked about TRANSITE* PRESSURE PIPE

*Transite is a registered Johns-Manville trade mark

1. What is Transite Pipe's flow coefficient?

The conservative "C" value for Transite Pressure Pipe is 140, based on the Williams and Hazen formula.

2. Is Transite Pipe subject to tuberculation?

No! Transite's asbestos-cement composition is assurance that its original high carrying capacity cannot be reduced by tuberculation.

3. What economic advantages result from Transite's immunity to tuberculation?

Transite's complete freedom from tuberculation provides substantial savings in the initial cost of the system as well as in maintenance and operating costs.

It means, first, that you don't have to resort to larger-than-necessary pipe to offset the progressive reduction of carrying capacity caused by tuberculation. Without "over-designing," you can specify minimum size pipe to do the job intended—providing flow for present needs and those incident to increasing population and industrial growth.

It means also that the pipe you install *now* won't have to be cleaned, lined, reinforced with additional mains, or replaced altogether because tuberculation has clogged its interior and reduced its original carrying capacity.

4. How about pumping costs?

Here again, Transite's non-tuberculating asbestos-cement structure pays off. In a Transite line it is not necessary to increase pumping pressures to compensate for the effects of tuberculation. Thus, pumps can operate at higher efficiencies—an economy which is helping to keep down water rates for the taxpayer in many communities served by Transite water lines.

5. Does Transite withstand corrosive soils?

In just about every type of soil, Transite has demonstrated its superior resistance to soil corrosion. This statement has been substantiated by impartial comparative studies conducted both by government and private agencies.

For example, one series of studies revealed that the corrosive effect of many types of aggressive soils on Transite Pipe was practically negligible after exposure over an extended period. Other pipe materials subjected to the same tests were substantially affected by corrosion, but the strength of the Transite Pipe actually increased under identical test conditions.

Another indication of Transite's unusual corrosion resistance is its performance in coal mine service. Here, the conveying of acid mine drainage waters is a severe test of the corrosion resistance of any pipe—so severe that the life of a drainage line is sometimes measured in terms of months or only weeks. Yet under these conditions some of the earliest coal mine installations of Transite Pipe, laid more than 12 years ago, are still in use today. Several of them have

outlived the mines in which they were originally installed and are now serving in new operations.

6. What about electrolysis?

Electrolysis is no problem in a Transite water line, for Transite, being non-metallic, is immune to electrolytic action. You can lay this pipe alongside street car or power lines or in the proximity of power stations, with complete confidence that it cannot be harmed by stray ground currents.

7. How about strength?

Three factors contribute to the high uniform strength of Transite Pipe:

1. Its tough, strong asbestos-cement composition (asbestos fibers have a tensile strength as high as 400,000 lbs. per square inch).
2. The method used to form the pipe during manufacture—it is built up under tremendous pressure into a dense, homogeneous structure.
3. The special curing process which follows the forming operation and develops maximum strength in the finished product.

And, Transite's resistance to virtually all types of soil corrosion is assurance that the strength which is built into this pipe at the factory *is built in to stay!* Its record of successful performance under adverse conditions is proof that Transite *maintains* its strength.

8. Does Transite Pressure Pipe provide tight joints?

Yes. Due to the Simplex Coupling, joint troubles in Transite lines are few and far between.

The design of the Simplex Coupling is simplicity itself. Consisting only of a Transite sleeve and two rubber rings, it is, in effect, a factory-made joint which is merely *assembled* on the job. The operation requires only that the sleeve be pulled over the ends of the pipe, which rolls and compresses the rubber rings into place between sleeve and pipe. Thus rubber, which provides one of the most effective of seals, safeguards the tightness of the line. Furthermore, each joint is readily checked for proper assembly as the pipe is laid, providing advance assurance that the line will pass leakage tests.

And because it is a *flexible* joint, the Simplex Coupling offers an important additional advantage after the pipe is in service. Its flexibility helps compensate for soil movement and other stresses to which the pipe may be subjected, thereby helping protect against joint leakage. This also provides a safeguard against washing away of the supporting soil and possible pipe breakage.

9. How much deflection is possible at the joints?

A deflection of 5° or more at each joint is possible on most installations of Transite Pressure Pipe—an important advantage when laying pipe around curves and in hilly terrain.

10. What installation economies does Transite provide?

It is an exceptionally economical pipe to handle and install. The lightweight sections make the use of mechanical handling equipment unnecessary except for the largest sizes. The Simplex Coupling employed assures a fast assembly job in the trench. Under most conditions, the pipe can be laid as fast as the trenching machine can do its work. In fact, because of this feature, many installations have been made with the same foreman supervising both excavation and pipe laying. And because of its rapid assembly, pipe installation jobs are completed sooner, minimizing street tie-ups and traffic annoyances.

11. Are service connections easily made?

Yes. Transite Pipe can be drilled and tapped with standard tapping tools and methods. Connections are strong and watertight. Connections to valves and fittings, cut-ins for valve insertions and branch take-offs, etc., are made by conventional methods.

12. In what diameters is Transite Pressure Pipe made?

Designed for both supply and distribution lines, Transite is made in diameters ranging from 4″ up to 36″.

13. What working pressures will Transite handle?

Three classes are made—for working pressures of 100, 150 and 200 pounds per square inch. To assure an ample factor of safety, each length of pipe and each coupling is factory tested before shipment at four times its specified working pressure.

Have you any further questions?

If you would like additional information about Transite Pressure Pipe, send for brochure TR-11A. Or if you prefer, ask to have a Johns-Manville representative call. Address Johns-Manville, Box 290, New York 16, N. Y.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville TRANSITE PRESSURE PIPE

An Asbestos Product

VALVE AND PRIMER CORPORATION

30 WEST WASHINGTON ST., CHICAGO 2, ILL.

Apco Automatic Pump Primers ***Apco Automatic Air Relief Valves***

V-Apco Automatic Vacuum Primers

V-APCO Automatic Vacuum Primers and APCO Automatic Pump Primers

Advantages

V-APCO Automatic Vacuum Primers for centrifugal pumps offer these advantages: 1) Keep pumps always primed. 2) End loss of time due to lack of prime. 3) Operate at any vacuum under which the centrifugal pump will operate. 4) Uses no foot valve. 5) Flexible capacity; will serve additional pump installations satisfactorily. 6) Does not affect pump efficiency. 7) Improves operation of pump. 8) Simple design insures long life, freedom from trouble, highest efficiency.

How the Primer Operates

Drawing below shows the V-APCO Primer. A priming valve of the 200 series is placed on the vent of the centrifugal pump. While the vacuum pump is producing a vacuum, the valve passes all air that

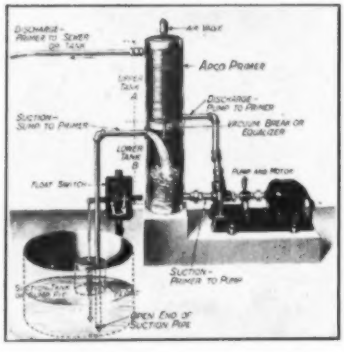
may be in the pump or suction line. When the air is withdrawn, it is followed by water which raises the valve float. That closes the outlet and prevents flooding of the vacuum pumps.

The Air Release Valve is mounted on the pump and connected to the vacuum storage tank that stores enough vacuum to act as a cushion on the vacuum pump. It provides a way to withdraw small amounts of air from the pump and suction lines from time to time. This makes frequent starting and stopping of the vacuum pump unnecessary.

A vacuum breaker on the vacuum tank unloads the vacuum pump in the unlikely event that is required. A vacuum switch with vacuum release connections is mounted on the vacuum tank and starts the vacuum pump when the vacuum drops in the storage tank and stops the pump when full vacuum has been reached. The vacuum release connection unloads the vacuum pump when it is not operating and places it in condition to start at no load.

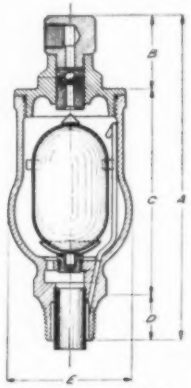
The check valve between the switch and the pump is a special noiseless one for the purpose, holding the vacuum in the storage tank when the pump is not operating.

THE APCO PRIMER

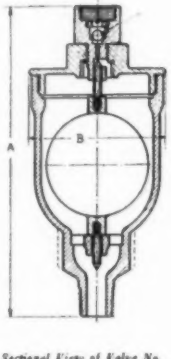


How the Apco Primer Works

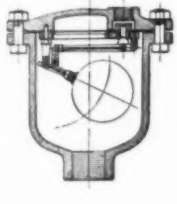
This cut shows primer in service with the pump running. When the pump starts, it draws liquid from the lower chamber of the primer and discharges it through the upper chamber. The withdrawal of the liquid from the lower chamber creates a partial vacuum in this chamber which causes the liquid in the sump or well to rise in the suction pipe and flow through the primer to the pump. When the pump stops, the liquid in the upper chamber runs back through the pump into the lower chamber by gravity, thus refilling the lower chamber with liquid to prime the pump when it starts again.



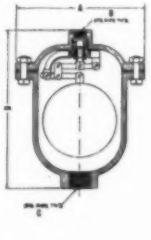
Sectional View of Valves Nos. 50-60 for Pressures Up to 60 Lbs.



Sectional View of Valve No. 50 H.D. for Pressures up to 150 Lbs.



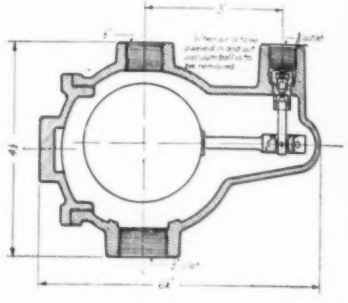
Sectional view of Valve No. 200. The valve has large venting capacities and positive opening when under vacuum.



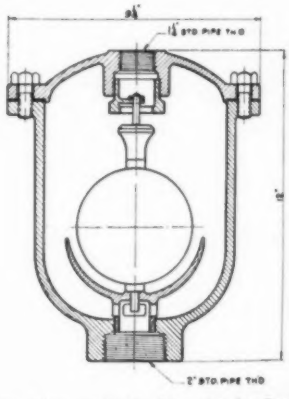
Sectional view of Valve No. 200-A.

APCO-Air Release Valves

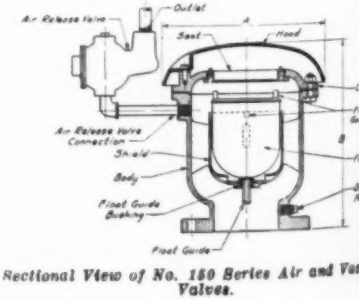
APCO Air Release Valves are made in 17 different sizes and capacities varying from the smallest with ⅜" pipe connection and small venting capacity to our large 2" size with an opening of 1" diameter and vacuum and air release valve from 2" to 6". We illustrate below a very few of these types. Your venting problems can be handled by some one of our valves in the proper manner. Prices are reasonable



Sectional View of Valve No. 55.



Sectional View of Valve No. 140 for Deep Well Pumps.



Sectional View of No. 150 Series Air and Vacuum Valves.

CROSS-CONNECTION RULES

By JOHN H. MURDOCH, JR.
Principal Attorney
American Water Works and Electric Co., Inc., New York, N. Y.

SOME recent epidemics of water-borne diseases have shocked water works operators into thought and action on an old problem. These epidemics have demonstrated to many what had been previously realized by some, namely: that if lines carrying potable water are connected directly or indirectly with facilities carrying water of questionable character or containing chemicals, impurities or deleterious matter of any kind there is always a possibility of the potable water becoming contaminated. Such contamination may result as an illustration, when the pressure in the lines carrying the potable supply is so reduced that it is lower than the pressure in the connected lines carrying questionable water and the questionable water becomes mixed with the potable water. Or back-syphonage due to reduced pressure may draw contaminating matter into the potable water supply lines of the premises. Such contamination might even be drawn into the general distribution system of the water purveyor, thus endangering the health of the general public and not merely those on the premises directly involved. These potential hazards impose a moral responsibility on water works operators beyond that of merely putting potable water into the distribution system. There is the added responsibility of taking reasonable precautions to guard the water in transit.

In recognition of this added moral responsibility all of the seventy odd operating water companies in the American Water Works and Electric Company system have recently adopted new rules and regulations concerning cross-connections and interconnections. These rules with their forms are set forth, complete, at the end of this article. In them a cross-connection is defined as ". . . any pipe, valve, or other arrangement or device connecting the pipe lines of the company . . . with pipes or fixtures supplied with water from any source other than the lines of the company." Under this definition there is a "cross-connection" if the company supply be connected with a second source even though the second source of supply be another public water supply system furnishing approved potable water. However, the company classifies that special type of cross-connection, if made with the knowledge and consent of the company, as an "acceptable cross-connection."

Classification of Cross-Connections

All other cross-connections are classed as "objectionable." The company makes it a violation of its rules for any customer to install any new "objectionable" cross-connection and will have the right to discontinue water service to a customer violating this rule.

"Objectionable" cross-connections installed prior to the new rules may be brought into a class known as "tolerated cross-connections" if they meet all the requirements for such classification. The requirements are found in the definition included in the rules and in the substance of the various "Forms." It should be noted that an "objectionable cross-connection" cannot be classed as a "tolerated cross-connection" if it in any wise lacks conformity with health department or plumbing regulations. On the other hand, a cross-connection might measure up to such rules and regulations and still not be accepted by the company as "tolerated." The sanitary engineer, manager and president of the water company might feel that they were not justified in jeopardizing the health of consumers through continuance of service to a customer having a cross-connection installation meeting public regulatory standards but still, in the opinion of company officers, constituting too serious a potential hazard. Conformity with public regulations is a prerequisite to qualification for "toleration," but such toleration is a subsequent independent action by the company in performance of its public obligations.

At this point, as an aside, the writer would like to suggest to health authorities that the word "approve" be not used by them in passing on applications for cross-connections. "Approve," to most minds, carries the idea of "esteeming as good" and not the idea of a reluctant consenting to something less than a completely desirable condition. As it is now recognized that all cross-connections are undesirable as constituting sanitary defects in a potable water supply system, surely it is better merely to "tolerate" those meeting certain standards than, by the use of the word "approve," to give the owner of the connection the idea that the cross-connection is good and given a blessing by a public finding to that effect.

Under the American Water Works system's new rules, the continuance in existence of an objectionable cross-connection which has not been brought into the class of tolerated cross-connections would constitute grounds for discontinuance of water service. Since no new objectionable cross-connections will be permitted and since even existing tolerated cross-connections are continued on a merely temporary provisional basis, and since the owner of a tolerated cross-connection assumes rather heavy legal obligations in applying for continued water service to the premises, it is the company's expectation that in the near future it will be rid of known cross-connections except those with other adequately supervised public systems of potable water supply.

Interconnections

The company has defined an interconnection as "a plumbing arrangement, other than a cross-connection, by which contamination might be admitted or drawn into the distribution system of the company, or into lines connected therewith, used for the conveyance of potable water." There is support in the literature of the subject for this use of the word interconnection: however, in some states "interconnection" is used to refer to connections between two public water supply systems. There is not any generally accepted terminology for the various desirable and undesirable connections in water systems, so that it was necessary for the company to formulate its own terms and definitions of those terms. Perhaps the terminology could be improved but the use of phrases in the rules has been consistent with the definitions there established.

Interconnections as so defined are infinite in variety, may be scattered throughout the premises, and may even be unusual management of perfectly proper facilities. Because of these recognized facts, the company in its rules contents itself with reserving the right to discontinue water service to premises: (a) on receipt of an order from public authorities on the ground of dangers to health because of the existence of dangerous or potentially dangerous interconnections on the premises or (b) when the company has knowledge that public authorities have ordered an existing interconnection on the premises broken or discontinued and has knowledge that such order has not been complied with in reasonable time.

Legal vs. Moral Responsibility

The writer of this article read a paper entitled "Legal Limits of Water Supply Systems" at the 1944 Meeting of the American Water Works Association. That paper was published in the August, 1944, issue of the association Journal and also in *Water Works and Sewerage* for August, 1944. It was ended with the following paragraph:

"Water works operators must be interested in potential health hazards which may affect the potable water supply. There is a moral responsibility on the operator to use his influence to bring about better plumbing practices. There is a moral responsibility to take necessary action within his rights and abilities to remove the hazard to the system from sanitary defects which he knows exist or should know exist. The water works operator should not let it be presumed that he has promised to perform that which he cannot perform."

By the new company rules, it is believed that this company has moved to assume the moral responsibility referred to in the quoted pararaph. All of the company's influence will be exerted toward the elimination of sanitary defects. Exertion of that influence should tend to educate the public in the dangers of cross-connections and interconnections and may cause many to cooperate. There will be violations of the company rules which will not always be detected but a sufficient number will be detected to constitute object lessons and the mere adoption and publication of the rules will, we believe, lessen the number of objectionable cross-connections.

It must be recognized that some customers of water service need secondary sources of supply. As an illustration this is true of steel plants which need huge quantities of water for cooling — water in such quantities that no general service water supply utility could supply it on an economic basis without imposing unreasonable burdens on general customers. However, the need for a secondary source of supply is no excuse for the installation of objectionable cross-connections. The two supplies should be kept apart or, if that be impracticable, the public supply should be fed into a tank with float control and the outlet of the public water supply line should be well above the maximum water line of the tank. Sterilization of the secondary supply may also be re-

quired as the health of those on the premises should be considered as well as the protection of those outside. These are matters in which health authorities should be active leaders. The American system group of water companies does not expect to increase its business through the elimination of secondary sources of supply on customers' premises, but it does intend to work for the protection of its lines from contamination and toward increased safety from water-borne disease.

Even "Tolerated" Connections Undesirable

As has been stated before in this article, the new rules have been adopted by all the companies in the system and are in the process of being legally filed and published. Representatives of the companies have discussed them at length with many state health department officials and those officials have all expressed themselves as being favorably impressed. In one instance, where the state prohibits what are classified in the rules as undesirable but "tolerated" cross-connections, the company rules for this state have been changed so as to conform with general state regulations. Companies of that state can have no "tolerated" cross-connections. Our only regret in this respect is that more states have not taken similar action.

Several city councils have adopted ordinances legalizing the company rules. One state public utility commission granted the writer a hearing before the entire membership and then by formal vote permitted the rules to be filed as part of the tariff of all the system companies operating in the state.

Two remaining and all important steps are: the education of the public in the need for the elimination of improper cross-connections and interconnections and the enforcement of the rules. The company proposes to take both those steps.

The full text of the new rules follows:

RULES AND REGULATIONS*
TO COVER CROSS-CONNECTIONS AND INTERCONNECTIONS

Preamble

Reason for Rules and Regulations Concerning Cross-Connections and Interconnections and Methods of Enforcement

The Company accepts the judgment of various public health authorities that all connections or plumbing arrangements, which would or might permit water from other sources than the system of the Company or pollution or contamination from any origin to be drawn or admitted into lines carrying potable water furnished by the Company, constitute hazards to public health unless the connection be with a second source of supply which is an approved, acceptable, safe and sanitary source of public water supply. Even such an approved second source of supply should not be cross-connected with the supply from the Company lines unless such connection be approved by the health authorities and the Company.

The guarding of the potable water supply from or in the lines of the Company from possible contamination through objectionable connections on consumers' premises and outside of company-owned facilities depends, primarily, on the good sense, good faith and cooperation of the Company consumers, and next, upon vigorous action and cooperation from plumbing inspectors and public health officials. The Company, through the adoption of these Rules and Regulations and by continued enforcement of them to the extent of its ability, cooperates with consumers and with public officials in lessening the chances of contamination through objectionable connections.

Cross-Connections and Interconnections

I. Definitions

When used in these Rules and Regulations the following words and phrases shall have the meanings herein provided:

(a) *Cross-Connection.* A cross-connection is any pipe, valve or other arrangement or device, connecting the pipe lines of the Company or facilities directly or indirectly connected therewith to and with pipes or fixtures supplied with water from any source other than the lines of the Company directly connected.

(b) *Interconnection.* An interconnection is a plumbing arrangement, other than a cross-connection, by which contamination might be admitted or drawn into the distribution system of the Company, or into lines connected therewith, used for the conveyance of potable water.

(c) *Acceptable Cross-Connection.* An acceptable cross-connection is a cross-connection having all of the following characteristics:

1. The source of the supply other than the lines of the Company directly connected is a source approved by the State Department of Health as an acceptable, safe and sanitary source of public water supply and which continues as such at all times while the cross-connection is in existence;

2. Installed or continued in existence with the knowledge and specific consent of the Company, and when installed on the premises of a consumer, or installed by a consumer, such consent to be evidenced by either: (A)—Communications on Forms 1, 2 and 3, set forth in Section numbered V of these Rules and Regulations concerning Cross-Connections and Interconnections; or (B)—Existing installations continued in existence on the written authorization of the president of the Company.

3. Installed or continued in existence and operated at all times in strict compliance with all applicable laws, ordinances, rules and regulations.

(d) *Objectionable Cross-Connections.* An objectionable cross-connection is a cross-connection other than an acceptable cross-connection.

(e) *Tolerated Cross-Connection.* A tolerated cross-connection is an "objectionable" cross-connection having all of the following special characteristics set forth under either A or B:

A. 1. Installed and in service before the ———— day of ————, 194—;

2. Called to the attention of the Company by written application for Continuance of Water Service (Form 1) from the owner or occupant of the premises on which the cross-connection exists within ten days from the receipt by such owner or occupant of notice of the adoption of these Rules and Regulations;

3. Continued in existence on a provisional and temporary basis after the ———— day of ————, 194—, without discontinuance of water service on recommendation of a sanitary engineer for the Company, evidenced by written communication to the manager of the Company (Form 2), and with the consent of the Company evidenced by written communication from the manager of the Company (Form 3).

Or, in the alternative:

B. 1. Installed and in service before the ———— day of ————, 194—;

2. Continued in existence on a provisional and temporary basis after the ———— day of ————, 194—, on the written authorization of the President of the Company.

II. Prohibition of Installation of Cross-Connections

After the ———— day of ————, 194—, no cross-connection shall be installed or made unless such cross-connection shall be an "Acceptable Cross-Connection," as defined in these Rules and Regulations, and the installing or making or the causing or permitting of the installation or making of a cross-connection, other than an Acceptable Cross-Connection, after the said ———— day of ————, 194—, shall constitute a violation of the Rules and Regulations of the Company.

III. Prohibition Against Continuance in Operation of Existing Cross-Connections

After the ———— day of ————, 194—, no cross-connection shall be continued in operation or existence unless such cross-connection has and continues to have at all times the special characteristics required to qualify it as either an "Acceptable Cross-Connection" or a "Tolerated Cross-Connection," as those terms are defined in these Rules and Regulations, and the causing or permitting by any consumer or any owner or occupant of premises of the continuance in operation or existence of such cross-connection not in the accepted classes shall constitute a violation of the rules and regulations of the Company.

IV. Right of Company to Discontinue Water Service for Violations of Company Rules and Regulations Regarding Cross-Connections or on Order of Public Authorities

In addition to any or all other grounds for discontinuance of service, the Company shall have the right to discontinue water service on reasonable notice, not to exceed ———— days, under either of the following circumstances:

*A supplement to the "Rules and Regulations" of the several companies of the American Water Works and Electric Co., Inc.

1. Violation by a consumer or by a property owner or occupant of Company Rules and Regulations regarding Cross-Connections;

2. Receipt by the Company of an order from health authorities or plumbing inspectors to discontinue service to a premises on the ground of violation of Company Rules and Regulations regarding cross-connections, or on the ground of dangers to health because of the existence of cross-connections or interconnections on the premises;

3. When the Company has knowledge that health authorities or plumbing inspectors have ordered a cross-connection or interconnection, existing on the premises, to be discontinued or broken and such order has not been complied with.

V. Forms

APPLICATION FOR
CONTINUANCE OF WATER SERVICE TO
PREMISES ON WHICH CROSS-CONNECTION EXISTS

(Form 1)

Dated ——————————, 194—

To ——————————Water Company:

Applicant, ——————————, owner, occupant or water consumer at the premises known and described as follows: ——————————

——————————

does hereby make application for continuance of water service at said premises on which one or more cross-connections exist and makes representations and agrees and covenants as follows:

1. That the only cross-connections, within the definition of that term in the Rules and Regulations of the Water Company, existing on the above designated premises on the date of this application —————— located and described as follows:

2. That the blueprint— or drawing— attached to and made a part of this Application correctly and accurately portray the physical layout and details of construction of said cross-connection—

3. That the Applicant is familiar with all applicable rules and regulations of state and local health authorities and with any applicable laws, ordinances, rules or regulations concerning plumbing, and represents that the aforesaid cross-connection— may be continued in existence after the date of this Application without violating any such law, ordinance, rule or regulation.

4. That the Applicant will at all times operate and maintain the aforesaid cross-connection— in full compliance with any such law, ordinance, rule or regulation as is now in force, or as may hereafter be put in force by new enactment, promulgation, change, amendment or addition.

5. That the Applicant will make no change in the structure, character or method of operation of the aforesaid cross-connection— or create or install any new cross-connection— without prior specific and detailed written permission from the Manager of the Water Company issued pursuant to written recommendation from a sanitary engineer of the Water Company.

6. That the Applicant, for itself, its heirs, successors and assigns, hereby gives and grants to the Water Company the right, by its officers or agents, to enter upon and into the aforesaid premises at any reasonable time to observe and inspect the aforesaid cross-connection, or to determine for itself whether the Applicant has made any misrepresentation in this Application or has failed to keep and perform any agreement or covenant provided in this Application.

7. That the Applicant will either cause any cross-connection on its premises to be permanently and completely disconnected to the satisfaction of the Water Company or will not object to discontinuance of water service to the premises, if, when or as any misrepresentation or failure of performance by the Applicant be discovered touching any matter covered by this Application; or if the aforesaid cross-connection be not installed, operated or maintained in such manner as will, in the opinion of the Manager or Sanitary Engineer of the Water Company, safeguard the interests of the Water Company or its other customers; or if, in the opinion of the Manager of the Water Company, conditions are such that the aforesaid cross-connection— may be permanently and completely disconnected without unreasonable hardship on the Applicant; or if, because of the nature of the aforesaid cross-connection— or the manner of operation, this Application be not granted by the Water Company; or if the Company be in receipt of an order from health authorities or plumbing inspectors to discontinue service to the premises on the ground of dangers to health because of the existence of cross-sections or interconnections on the premises; or if the Water Company has knowledge that health authorities or plumbing inspectors have ordered a cross-connection or interconnection existing on the premises to be discontinued or broken and such order has not been complied with.

8. That the Applicant, its heirs, successors and assigns, covenant and agree that it will indemnify and save the Water Company harmless from any and all loss, damage, liability, claim or demand, arising from, based upon or caused by any condition or occurrence traceable to the continued existence or operation, after the date of this Application, of any cross-connection on the premises of the Applicant, whether or not specifically mentioned in this Application.

Signed, sealed and delivered by the Applicant the day and year first above written.

—————————— (SEAL.)

By ——————————

ATTEST:

——————————

(SEAL)

——————————

(Blue prints or drawings of cross-connection— are to be attached to the communication Form 1.)

RECOMMENDATION OF COMPANY SANITARY ENGINEER

(Form 2)

Dated ——————————, 194—

To ——————————, Manager of
—————————— Water Company:

I have examined the attached Application for Continuance of Water Service to Premises on which a Cross-Connection Exists, and the blueprints or drawings attached thereto. I have also, either in person or by an assistant in whom I have confidence and for whose work I am responsible, made such inspection of the premises and the cross-connections covered by the said Application as I believe to be necessary. I have also made myself familiar with the applicable laws, ordinances, rules and regulations.

On the basis of my examinations, studies and inspection, but relying upon the accuracy and truth of the representations made by the Applicant as to all matters where careful visual inspection could not reveal all facts and circumstances, I hereby recommend that the Water Company —————— continue water service to the premises covered by the Application without requiring the permanent and complete disconnection of the cross-connection— existing thereon and mentioned in the Application.

——————————

Sanitary Engineer for
—————— Water Company

AUTHORIZATION

(Form 3)

Dated ——————————, 194—

To —————————— Applicant

Acting in reliance upon your representations, agreements and covenants, and also on the Recommendation of the Sanitary Engineer for the Water Company, the Water Company will continue water service to the premises covered by your Application without requiring that you permanently and completely disconnect the existing cross-connections mentioned in your Application.

The granting of your request in your Application is subject to the understanding that service will be continued to the premises in question without permanent and complete disconnection of the cross-connection; only so long as the premises are owned or occupied by you or your heirs, or (if you are a corporation) by your successors in corporate existence; only so long as all representations made by you in your Application continue to be true, and only so long as you faithfully perform all of your agreements and covenants provided in your Application; and distinctly and specifically subject to the terms of paragraph 7 of your Application; and will be subject to review and re-examination not less frequently than once a year from this date.

—————— Water Company

By ——————————

Manager

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON NEW YORK SCHENECTADY PHILADELPHIA BUFFALO PITTSBURGH CHARLOTTE CINCINNATI ATLANTA DETROIT CHICAGO MILWAUKEE ST. LOUIS ST. PAUL NEW ORLEANS KANSAS CITY HOUSTON DENVER LOS ANGELES SEATTLE SAN FRANCISCO

BAILEY METER COMPANY LIMITED, Montreal, Canada

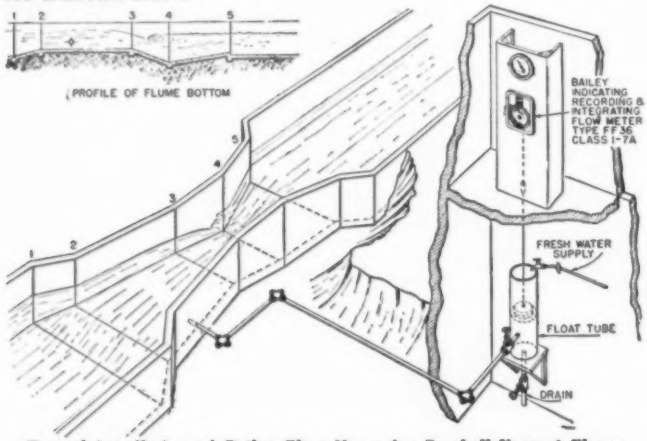
METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

Bailey Flume Meter—Simplicity of installation, low head losses and self-cleaning features of the Parshall Flume have resulted in a greatly increased use of this device for a measurement of Sewage Flow in open channels.

The Bailey Flume Meter is simple and accurate. As shown in the illustration, it consists of a single float which is connected by a flexible cable to the sturdy recording, integrating and indicating mechanism on the panel board. The panel board may be omitted if desired and the recording mechanism mounted on a wall or column. This device may be adapted to any type of open channel metering over any operating range required. Its capacity can be altered in the field by installing new gears and/or cam without disturbing any other parts of the installation.

Standard Bailey Indicating, Recording and Integrating Instruments are used, charts are 12 inches in diameter and uniformly graduated. Instruments may be placed in remote locations by the addition of Bailey Telemetering Systems. Ask for Bulletin No. 62.


PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF36 CLASS I-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

Typical installation of Bailey Flow Meter for Parshall Venturi Flume.

Bailey Weir Meter—For measuring flow using any type of Weir notch, highly accurate results can be obtained with a Bailey Weir Meter. This meter is similar to the Bailey Flume Meter and possesses the same features of sturdiness, flexibility and accuracy. Remote transmission can be provided when desired.

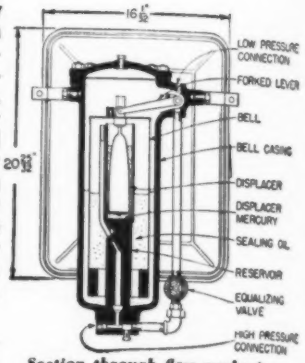
Open Float Type Meter—The Bailey Float Type Meter is especially adapted to measure the flow of sewage, sludge, dirty water or other liquids in pipe lines using a Venturi Tube, flow nozzle or eccentric orifice.

This meter is operated through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes. It is similar in external appearance to the Bailey Flume Meter.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey Register previously described. Remote recorders may be provided by Bailey Telemetering Systems which operate electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

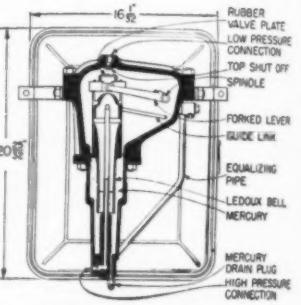
Described in bulletin No. 301-B.



Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 88-in. of water. *Described in bulletin No.* 301A.



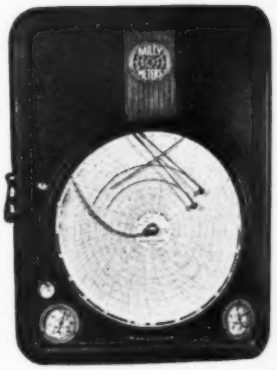
Section through flow mechanism of Ledoux Bell type Register.

Remote Registers — Bailey Telemetering Systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi Tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey Gages and Registers.

Bailey control is fully automatic, dependable and exceptionally flexible.



Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

RATES AND REGULATIONS FOR WATER USED IN AIR CONDITIONING*

A panel discussion

By Frank C. Amsbary Jr., Elwood L. Bean, Ted H. Kain, Lynn B. Mighell and Marsden C. Smith

Frank C. Amsbary, Jr.
Mgr., Illinois Water Service Co., Champaign, Ill.

FOR years the operators of water utilities have looked with envy at the innumerable electrical load-building appliances that have been produced and placed on the market. At last, a load builder, air conditioning, has been developed which will add greatly to the revenue of water properties, and now certain groups in the industry start talking of "special rates" and "special regulations" to curtail this use of water. Are these men being short-sighted or do they have a real basis for concern? Is this a desirable type of load builder?

Outline of the Problem

Disposing of the comparison with the power industry first, their business is essentially to render a service; the water industry must not only render a service but also deliver a commodity, tons upon tons of it. Because the problem of transportation is added to that of service, no valid comparison can be made between the two types of utility.

The demands of air conditioning on the water system vary from city to city, depending upon the temperature of the water used. Thus, a community using wells with temperatures around 50°F. has a very different problem from one where the source is an impounded surface supply. In the community with the well supply, the cooling of the air may be accomplished merely by passing it over water-cooled coils. It has been found that such installations may require as much as 8 gpm. per equivalent ton of refrigeration. Compare this with the community which depends upon a surface supply: the temperature of the water is so high that the situation demands refrigerating equipment, which will require only approximately 2 gpm. per ton of refrigeration.

Geographic considerations have a great bearing upon the effect of air conditioning demands on water systems. For example, investigation disclosed that, generally speaking, water plant operators in Canada are not particularly concerned about the problem. The daily temperatures are relatively moderate; the hot days are few and the summer season is short when compared with climatic conditions in the Mississippi Valley or the southern states. Identical buildings would require equipment of smaller capacity in Canada to effect the same comfort as in the Mississippi Valley. The air conditioner would be used to capacity for fewer days during the summer season, and the shortness of the season would further reduce the total days of use.

In studying this problem it must be remembered that the physical plant of the water property—that is, the source of supply, water treatment plant, storage facilities, heavy-duty pumping and distribution system—must be designed and built to handle the seasonal and daily peak air-conditioning load in addition to ordinary consumption and fire-fighting demands. The daily peaks in cities of the United States from which the author has received data indicate that air-conditioning loads will run from 22 to 100 per cent of the daily average plant output. This excess water is being used on peak days in a period of from eight to twelve hours. There is an economic limit on the size of plant that can be built to meet such loads and exist under the present rate structure. Such a limit will vary with each individual property.

Methods of Control

The definition of reasonable control is considered to be an individual plant problem, but the author believes that prohibiting the use of water-cooled coils when wells are the source of supply is justified both economically and from the standpoint of conserving a natural resource. Such a prohibition would require the customer to install refrigerating equipment, which may be equipped with water conservation auxiliaries if conditions warrant.

Another approach toward conservation is the imposition of a surcharge for water used in air conditioning without conservation equipment. The proponents of this school of thought claim that, if customers desire to use the water wastefully and will pay the higher costs, the revenue so derived will support the additional plant facilities required. But if customers do not wish to pay these surcharges and install conservation equipment to avoid them, there will be only nominal demands placed upon the system, which may be readily absorbed by the existing plant. The difficulty in determining a surcharge that will equitably carry additional fixed charges and operating expenses to meet this demand is apparent and, when arrived at, would probably be so high that it is not worth the bother to compute it. Such a rate would very likely cause everyone to install conservation equipment immediately.

Illinois Study

Champaign and Urbana, Ill., depend for their supply upon well water having an average temperature of 54° at discharge.

TABLE I

Champaign-Urbana Rate Schedule

Amount per Quarter, cu. ft.	Rate per 100 cu. ft.
First 9,000	$.25
Next 9,000	.18
Next 9,000	.10
Over 30,000	.06

Although there is some rise in temperature by the time the water is delivered to the customer, it is still well within the acceptable range in which water-cooled coils may be effectively used. As previously pointed out, such equipment uses large quantities of water—as high as 8 gpm. per equivalent ton of refrigeration. In the late 1930's this demand began to present quite a problem and a study of controls was undertaken.

The results of this study and the action initiated to effect conservation have previously been reported[1]. A very brief review will provide a background for understanding why the regulations adopted proved ineffective and new ones had to be developed.

The study disclosed that, under the present rate schedule (*see* Table I), it is cheaper for a customer to take water at 58°F., use it and throw it away than to install refrigerating equipment with recirculation. It was also found that air-conditioning installations in which water from the city mains (at a temperature of 58°F.) is used as a direct cooling medium in extended surface coils will require 3-8 gpm. of water per equivalent ton of refrigeration; that conversion to mechanical condensing units with conventional shell and tube—or pipe—condensers would save 73 per cent of the water previously used; that if evaporative condensers were added to the mechanical condenser units, a further saving of 22 per cent would be effected, or a total saving of 95 per cent of the water used in the first installation described; and that over 60 per cent of the total air-conditioning installations employed in the United States in 1941 were either air-cooled or used cooling towers, evaporative condensers or the like, thus practically eliminating any demands for city water.

To force the customer to install refrigerating apparatus with a recirculating device, or conservation equipment, the Illinois Commerce Commission approved an application of the Illinois Water Service Company to deny any customer the benefit of the last two steps in the rate schedule unless such conservation equipment was installed. This established a surcharge and, although it increased some customers' bills as much as 150 per cent, it was still cheaper to use the water and throw it away than to install refrigerating and conservation equipment. The increased revenue so derived would not carry the fixed charges on necessary added plant investment and operation. Nothing had been gained. Two alternatives presented themselves: to revise the surcharge by actually computing an equitable rate on the basis of the actual plant investment plus operating costs required to supply the air-conditioning demand; or merely to restrict the use of water. A preliminary review of the factors that would enter into the establishment of an equitable surcharge indicated that the rates would be so prohibitive that, in effect, the result would be the same as establishing rules restricting the use of the water.

Regulations Adopted

Having reached this conclusion, in 1946 the company petitioned the Illinois Commerce Commission, requesting that the rule authorizing a surcharge be cancelled and submitting a set of regulations which was approved and has been found effective. These rules governing the use of water for summer comfort air conditioning or refrigeration read:

In all apparatus or equipment installed for the purpose of changing the dry bulb temperature or humidity content of the

*Reprinted from *J.A.W.W.A.* Vol. 40, p. 809 (1948) by permission.

air, whether used in conjunction with summer comfort air conditioning or other refrigeration, the following regulations shall apply:

(a) The use of water is prohibited when used directly from the mains as a cooling medium in air washers or any type of equipment whereby the air to be conditioned comes into direct contact with sprays or wet surfaces, or where the water is used as the direct or indirect cooling medium in coils.

(b) The use of water is prohibited in all compressor-type refrigeration units having standard rated capacities* of 1½ tons or less.

(c) All compressor-type refrigeration units having standard rated capacities* of from 1½ to 5 tons may be equipped with water-cooled condensers using water from the mains; provided that not more than one such unit with such capacity and so equipped may be used in an air-conditioning or refrigerating system, except for emergency stand-by purposes.

(d) All compressor-type refrigeration units having standard rated capacities* of 5 tons or over shall be equipped with evaporative condensers, evaporative coolers and condensers, water cooling towers, spray ponds or other water cooling equipment so that all water from the mains is used for make-up purposes only.

(e) If other than compressor types of refrigeration units are used, the consumption of water from the mains shall be limited in amount to not more per ton of refrigeration produced than would be used by the compressor type described under (c) or (d) above when such type is operated under normal conditions.

Failure to comply with the above regulations shall be sufficient cause to discontinue service.

Elwood L. Bean

Prin. Asst. Engr., Philadelphia Bureau of Water, Philadelphia.

The extent of control necessary, or desirable, is an individual problem for each water supply, and is dependent on many factors. The quantitative and capacity aspects of the problem have been outlined by Frank C. Amsbary. (Control of the sanitary aspects is not part of this discussion.) The most urgent topic is, of course, the matter of the quantity of water required and the capacity of the water works system to deliver that quantity. Statistics on the number of systems capable of fulfilling expanded demands may be derived from recently published surveys. It appears that 40 per cent of the water supplies of the larger cities should definitely have air-conditioning regulations in effect, though actually only about 10 per cent have any such rules or practice any volume control.

Condition of Water Supplies

In setting up any classification the limits must necessarily be somewhat arbitrary, but, taking into account the excesses of peak loads over the average, the author suggests that when use during the six months from May through October averages 90 per cent or more of the rated capacity of the water works, the condition should be considered critical. Likewise, when usage on the same basis exceeds 70 per cent, the time has arrived for a serious study of methods of limiting it.

According to these criteria, a recent survey[2] of 56 of the larger cities shows that 13 of the supplies should be considered critical and an additional 18 should study limitations. Only 25 of the systems can be classed as having a capacity which is adequate for more than the next few years, and only about one-half of this number have sufficient capacities to warrant actively encouraging increased water usage.

These facts would indicate that the water works systems of America may be divided into four approximately equal groups: (1) those which must be worrying daily about the adequacy of their supply, (2) those which should be studying or working for additional capacity, (3) those now enjoying safe balances of supply and demand and (4) those which should be encouraging sales to obtain increased revenue.

Quantities Used

In 1937 New York City calculated[3] a wastage for the summer season of 34 mgd., or 3 per cent of the total supply, by units which were not equipped with conservation devices. The amount of conserved use was not determined but was in addition to the 34-mgd. wastage.

In 1936 Chicago estimated the use of water for air conditioning in the central business district (the Loop) at 34-mgd. Assuming the rate of increase for this use to be the same as the rate for total demands in the Loop area, the total demand for air conditioning would have been 42 mgd. by 1945. Complete conditioning of the Loop area with unconserved units has been estimated to require 295 mgd.

Baltimore, Md., estimated that the use for air conditioning in the central city in 1947 reached 2,000,000 gph, which equals a rate of 48 mgd.

In Philadelphia for 1947, assuming that existing regulations are strictly complied with and, therefore, that all units over 30 hp. have conservation while none under 30 hp. are conserved, the use would have been 30 mgd., or approximately 7 per cent of the 439-mgd. maximum day's use in the system.

For the central area of Philadelphia, the use was calculated as 22 mgd., or 11 per cent of the total use in the area. It is the belief of the author that the use in Philadelphia is even greater than is indicated by these calculations[4] made for 1947.

Existing Regulations

In a round table[5] involving 36 water systems in 1945, only three noted any regulations, and these required only that all water for air conditioning must be metered.

A recent survey[2] indicated that, of 56 systems, only New York and Philadelphia have any official general restrictions on the amount of water use.

New York City's regulations have been described in an *A.W.W.A. Journal* article.[3] Briefly, metering is required where the minimum rate for operation exceeds ½ gpm., and economizers where the use exceeds an annual average of 5 gpm. Separate metering may be required if the unit rating is over 25 tons, or the use exceeds 50 gpm.

The 5-gpm. average allowed without conservation equals 2.6 mil.gal. per year. Since the total demand-hours use is frequently calculated at 1,000 hours per year, then, under the New York City regulations, the use when operating may be about 6 cfm.; if the unit were operated only 600 hours per year the demand might be near 10 cfm. before conservation was required. In an actual installation consisting of a 40-ton and a 20-ton unit, only one of which was ordinarily operated at a time, the total use did not exceed the 5-gpm. annual average; no conservation was therefore required, yet this unit represented a peak load exceeding a daily rate of 170,000 gal. Because this flow would be ample for conserved units totaling more than 2,000 tons, it is evident that such a regulation accomplishes comparatively little, if anything, in the way of reducing peak loadings.

Philadelphia requires economizers where the maximum use exceeds 10 cfm. All new services must be metered, but separate metering of the water for refrigerative purposes is not required. This limit allows the operation of units of about 30 tons before conservation is obligatory. The amount of water needed for a 30-ton unit could serve an installation of over 750 tons, if properly conserved.

Detroit, Mich.; Newark, N.J.; New Orleans, La.; Pittsburgh, Pa., and the District of Columbia grant permission for an installation only where the main capacities are sufficient. Wichita, Kan., excludes the discharge from sanitary sewers if the use exceeds 1 gpm.

Ten other systems are known to have considered regulations but have not enacted them. For three of these systems the May-October average was over 90 per cent of the rated capacity; for three others the percentage was 68-75; one each had a percentage of 63 and 40; and for two systems the percentage was unknown. Unless prospects for the expansion of supplies are developing, six of these systems should adopt regulations to control the demand.

Edmonton, Can., on the other hand, with a May-October average which is only 48 per cent of the capacity rating, indicates an extreme situation, as it is estimated that 30 per cent of the supply will be available for air conditioning for the next ten years.

Metering

No private utility would consider selling a product without a real measure of the quantity delivered, nor should a public utility. The metering of water should be required for all installations. This raises the question of separate metering for air-conditioning equipment. New York City *may* require a separate meter[3] on all units over 25 tons or 50-gpm. use, but the billing of water is based on the total used on the premises.

This method of billing leaves the customer paying for air-conditioning water on an increment basis. Separate billing would entail the minimum charges attached to such a service and would produce an added revenue. Would this amount be sufficient to cover the additional expense of metering, billing and miscellaneous costs attached to each service added to the listing, and also provide a surplus which might be considered as a partial return for the stand-by nature of the service?

Solely as a method of controlling the quantity of water used, the installation of a separate meter seems unnecessary. The horsepower or tonnage of the unit can be used as the basis for regulations.

Each unit manufactured is equipped with a thermostatic valve which limits the water use to that amount necessary to remove heat from the unit. The condenser temperature setting is adjustable, however, and it is this setting which controls the amount of use. Neither the maximum rates of water use nor the amounts of water involved can be readily calculated for unconserved units. No practical basis for determining uncon-

*Note: in *(b)*, *(c)* and *(d)* capacities shall be in accordance with conditions given in Standard A.S.R.E. [American Society of Refrigerating Engrs.] Testing and Rating Codes.

served use can be obtained except by meter readings.

In each system, the means of billing to produce desired results should be worked out. The objectives will vary with the circumstances of the various systems. The aim may be to reduce water use or to derive only a reasonable profit from the service provided.

Flat Rates

Theoretical calculations from the water temperatures can be used to establish a water-use curve for operation throughout the year. The actual loading of the unit can be estimated from existing data, and from these results the annual use may be calculated. Rates can then be established. These must be set at very high levels, however, if the system is always to receive a reasonable return.

The use of flat rates where avoidable cannot be advised. Even on conserved units metering should be required, because flat rates on units equipped with economizers can be the cause of serious loss to the water works. For instance, suppose a 20-ton installation equipped with a water cooling unit was billed on the basis of the water which should be required (not more than 2.0 gpm.). If the recirculating equipment were shut down and tap water run through the unit, its capacity might be somewhat reduced from its rating. But, under flat rates, operators have no incentive to keep the adjustments set at the minimum water use consistent with satisfactory operation. Consequently, a saving would result to the customer, and a loss of 20,000 to 70,000 gpd. to the water works.

In New York City, regulations require metering, as previously mentioned, but for unmetered use a flat rate of $30 per year per ton is established for unconserved units. For those conserved to below 15 per cent of unconserved demand, the rate is $4.50.

Even a flat rate of $30 per year per ton may not be sufficient if the water is not conserved. The possibilities of water waste are astonishing.

At Philadelphia water temperatures, the necessary water use, without conservation devices and assuming an average discharged cooling water temperature of 96°F., would average about 1.2 gpm. per ton from May to October. With a proper charge for water, the actual use would not average far above this. At a maximum-day supply water temperature of 85°F., the use would reach 2.7 gpm. If water is sold at a flat rate, the customer has no interest in economizing on its use, but he can save money on electricity. He will therefore set the condensing temperature at a lower point. Suppose he sets it at 96° F.; the discharge water temperature will be, say, 86° F. The temperature of the water in the supply rises to 75°, and the use will be about 2.7 gpm.; at 78°, the use will be 3.75 gpm.; at 82°, 7.5 gpm.; and at 85°, the required flow of water becomes 30 gpm. per ton, of which about 27 gpm., or 39,000 gpd., is unnecessarily wasted.

It can be seen that the only limit on the water actually used in many flat-rate, unconserved units would be the size of the service to the unit. If any flat rate is to be established it should probably be on the basis of service size.

New Regulations

The relationship between capacity and peak demands, the present high use for air conditioning and the probable rapid increase in refrigerative uses, seem to make it necessary for at least 40 per cent of this country's water systems to adopt regulations which will limit the demands and maximum usage and prevent waste. Because of the comparatively low water requirements of properly conserved units, there are few, if any, systems which need to restrict the tonnage installed.

Limits for the regulation of unconserved use should be set up on the basis of the maximum actual demand of units, or on their tonnage rating, and not on the average water use. This was demonstrated in the previous discussion of the existing New York City regulations.

In Philadelphia, studies have indicated that it is not usually economical to install units of over 10 or 15 tons without conservation. With increased water and sewer rates, the 10-ton limit will probably be the largest size generally economical. In many systems the much higher water rates indicate even smaller units. The size to be set as the top limit for unconserved installations should be determined by water works officials and should principally be based on the exigency of reducing demand, but consideration should also be given to the economic situation of the consumer.

Metering should be required for all installations but need not be separate.

The author does not believe that new or special schedules of rates should be established; existing rates should cover the situation for metered water. If additional revenue is needed, the entire rate schedule should receive an overhauling. It does not seem necessary to establish special higher rates for air-conditioning use than for other usage of like quantity. This statement is based on the belief that, although four large cities have indicated usage in excess of 30 mgd., this could be reduced to one-half by a 10-ton limit on unconserved units. With conservation there would probably be no more than a half-dozen installations in a city which would use over 50 gpm. (equal to about 1,000 hp. in size).

Ted H. Kain

Gen. Mgr., Columbia Water Co., Columbia, Pa.

Although most water companies have not yet felt any real need for special rates or for regulations governing air conditioning, consideration and study should be given to this growing industry by water works men. One of the most important subjects to be discussed at this early stage of development is the question of water conservation requirements, which is always a good water works practice.

Water Sources and Requirements

The sources of cooling water include private supplies—both surface and underground—and water from city mains. Well water, if the quality is satisfactory and it can be obtained in the necessary quantities, is almost certain to be the best source of cooling water because of its constant cold temperature. Surface water—including rivers, lakes, ponds and streams—is the least commonly used source of condensing water because of the problems of quality, the presence of foreign matter and the depth of the water at extreme low-level conditions. The use of water from city mains requires the smallest investment for equipment and the least attention in operation. The cost of the water may be high, but, since less equipment is involved, expenditures for depreciation, maintenance and other fixed charges are low. According to air-conditioning and refrigeration manufacturers and representatives questioned by the author, over 90 per cent of the water-cooled installations are supplied through city mains.

The average cooling water requirements appear to be in the range of 1.5-3 gpm. per ton of refrigeration. One manufacturer estimates that 3 tons of refrigeration requires 4 gpm.; 5 tons, 6 gpm.; 10 tons, 12 gpm.; and 15 tons, 17 gpm.

Table II lists the results of a U.S. Bureau of Census survey of 72 manufacturers of air-conditioning and refrigeration equipment and accessories. These statistics apply to equipment actually billed and shipped in the fourth quarter of 1947 and are therefore equivalent to completed sales for that period. It is startling to note from Table II that over 90 per cent of the air-conditioning and refrigeration equipment sold in the last three months of 1947 was without conservation. This same percentage holds good for the remainder of the year as well.

TABLE II

Refrigeration Equipment Sales, October-December, 1947

Equipment	Units Sold
Condensing units	9,805
Compressors and compressor units	5,490
Self-contained units	5,501
Total	20,796
Evaporative condensers (economizers)	1,131
Cooling towers and ponds	1,131
Total	2,262

All of the many different types of condensing water systems in operation fall into two general classes: (1) those in which the water is passed through the condenser and then wasted to sewers or used for some other purpose; and (2) those using spray ponds or cooling towers, in which the water is recirculated, with make-up water added to balance evaporation losses.

Local Regulations

From the statistics on cooling water sources and economizers, it is evident that the conservation of water is the air-conditioning problem about which water works officials should be most concerned. A rule restricting the waste of water for air conditioning should be adopted by every water company, borough or municipality.

In a number of localities such restrictions are now in force. Chambersburg, Pa., prohibits the installation of air-conditioning equipment of 5 tons or more unless an economizer or cooling tower is installed. New York City limits the wastage of an air-conditioning system for a single consumer to an annual average of 5 gpm. Miami Beach, Fla., prohibits the connection of water waste from air-conditioning systems to sanitary sewers if the units in question use more than 2 gpm. of water. In 1944 the Virginia Section, A.W.W.A., passed a resolution recommending that no utility should supply water from the public distribution system for any new, additional or enlarged refrigeration at a rate in excess of 0.05 gpm. per ton of refrigeration.

Rates for water for air-conditioning use should come under the water company's regular rate schedule, and the author does not believe that any penalty rate is necessary at present.

Conclusion

The use of air conditioning in stores, offices, hotels, barbershops, beauty parlors and the like is rapidly increasing. It is be-

ing adopted by professional men, industries and even churches. Within the next five years, home air conditioning with water-cooled equipment will become a significant factor, though residential installations today are practically all window models. Water works men should follow closely this growing demand on their systems and should be prepared with a policy to meet it.

(The paper by Lynn B. Mighell of The Carrier Corp., Philadelphia, dealt with cooling equipment and operation and is not reprinted here.)

Marsden C. Smith

Chief Engr., Dept. of Public Utilities, Richmond, Va.

There can be no doubt that water required for air-conditioning equipment presents a serious problem if it is to be supplied by the public water systems. But there are other demands that also create serious problems. Lawn sprinkling, swimming pools and similar seasonal uses of water are in exactly the same class and intensify the problem of hot weather peak demands just as does air conditioning. Therefore, in spite of the fact that the subject assigned to this panel is water use by air-conditioning equipment, it seems proper to extend the discussion to cover any use of water which creates an unreasonable demand.

Before attempting to determine the most successful means of solving the problems created by unreasonable demands, it should be ascertained that any proposed solution is both legal and reasonable. This is not only common sense but is necessary because there are some water utilities which are privately owned and others which are publicly owned. For this reason, a solution which may be approved by a city council for a municipal system may not be at all acceptable to a state commerce commission.

It should also be realized that the peaks due to seasonal demands do not cause equally serious problems throughout the limits of the area served by the A.W.W.A. In tropical climates the seasonal peak is lessened, or at least there is a far greater gross revenue obtained from hot weather sales than in those areas which have a short but intense hot weather period. And it is well to remember that the North American opposes specific high rates or any special regulations. He demands, and usually gets, pretty much what he wants, unless he can be convinced that he is not being treated unreasonably. He will claim discrimination just as quickly against a high special charge for service as he will against a denial of, or a regulation of, the conditions of service.

If, for example, the water purveyor attempts to limit the water used for air-conditioning equipment by specific rates, the customer may claim, with much justification, that lawn sprinkling creates an equally severe and unreasonable demand. Then, if the purveyor is to escape this charge of discrimination, he will have to accept the serious complications in metering, billing and accounting that must be incurred because of the special rates necessary for each of the seasonal peak demands.

On the other hand, the customer will undoubtedly register an effective complaint if he should be denied the use of water for air-conditioning equipment and at the same time see his neighbor continue lawn sprinkling, using a swimming pool or some other equally nonessential seasonal utilization of water. This would most certainly constitute flagrant discrimination.

Compromise Solutions

The author is therefore strongly opposed to any limitation on the use of water that can be avoided without serious consequences. Several instances may be mentioned of unreasonable demands which have been checked by an appeal to reason, and in none of these have specific rates been required to protect the system. Indeed, it is probable that had the effort been made to cover the higher expense of certain of these services by specific rates, the increased cost of the resulting complications would have largely cancelled the increased revenue obtainable.

The first of these unreasonable demands occurred when the owner of a large estate applied for water service to supply several hundred lawn sprinklers. To permit all of these sprinkler heads to be operated simultaneously would have required a major enlargement of the water distribution system, useful for only a few hours each year. The solution of this problem was to limit—not deny—the demand; this meant operating the sprinklers by sections rather than all at the same time. The solution was accepted by the customer as a reasonable regulation.

A different problem was created by the request of a railroad for a 4-in. connection to be used only for quickly filling diesel locomotive tanks. Such sudden variations in demand would have caused serious pressure fluctuations and adversely affected other consumers. The total volume was much too small to justify the cost of an enlargement of the distribution system. The solution adopted was to permit a service limited to a 90-gpm. rate to fill a tank erected at the customer's expense on his property. The railroad was entirely convinced that this solution was quite reasonable and fair.

A very different situation involved a swimming pool where proper sanitation required the use of as much as 1 mgd. when operating at the maximum attendance permitted. Naturally, the full use was limited to a few days a year, which exactly coincided with the days on which all other demands were at a maximum. The solution here was not to order the service discontinued but to limit the quantity of water to that necessary for make-up. The operator at first refused to install a circulating purification system but eventually gave in. In fact, he later actually requested a rebate to cover the losses he had been permitted to suffer before being forced to economize. If no special rate is charged for a bath at home on a hot day, it does not seem equitable to charge extra for a swim in a public tub.

Another variant of the problem is that of private fire protection. This is solved in one city by an ordinance providing that if the requirement for water for private fire protection necessitates the enlargement of the public distribution system, which, in the opinion of the manager, gives public protection equal to or better than the average for similar districts within the city, the entire cost of the new or enlarged system shall be paid by the beneficiary of the private fire protection. No charge is made for water used for fire protection, either from a city-owned fire plug or from a private system.

Still another problem was solved without the use of special rates or regulations. A water department was severely criticized for being unwilling to supply an unestablished manufacturer with more water than the entire city of 235,000 population normally used. Here the solution was one that had been fully established by other utilities. The city offered to supply the requirements, provided that the manufacturer would deposit with the city an amount equal to the cost of the system enlargements made necessary by his demand. The deposit would be repaid to the manufacturer at a fixed per cent of the gross charge for water at standard rates. No discrimination could possibly be claimed, because this is merely the same deposit required of all new customers, proportional to the risk involved.

These examples all indicate that specific rates are rarely necessary, certainly not when a reasonable solution can be obtained otherwise. They also show that water systems cannot escape the seasonal peak demands any more than can other utilities. But water works may properly use any reasonable means to reduce the severity of unusual or unreasonable demands.

Reasonable Reductions in Demand

To return to the subject of water required for air-conditioning equipment, the same principle clearly applies here as in the problems just described: a reasonable reduction in the intensity of the demand should be made, but there should be no denial of use nor any special rates, unless absolutely necessary.

Fortunately for everyone, water economizers are almost a necessity for large air-conditioning units, even when standard rates are charged for the water used. This fast tremendously reduces the seriousness of the problem.

For the smaller units, not now generally obtainable with economizers, it is quite probable that economizers or air-cooled units will be made available if the charges for water are sufficiently great to justify the added cost of such equipment.

For the immediate present, however, and until the magnitude of the problem is definitely established, it seems quite reasonable to require economizers for, say, individual units larger than 5 tons. Economizers would also be required for those units of 5 tons or less placed in a single building containing a total of more than a 5-ton rated capacity. All water would be supplied at standard rates.

After these regulations have been in effect for a reasonable time, and if in spite of them the demand is still found to create a problem, then further action can be taken. From experience thus obtained the necessity for far more drastic action can be demonstrated by facts rather than by anticipation. As a result, specific high rates may then be charged with full justification.

To sum up, it appears that a reasonable solution can be found for almost every problem without the complications of special rates or discriminatory regulations. But when special rates can be shown to be definitely necessary for the protection of the utility, they must be made sufficiently high to cover not only the cost of water service, but also the added expense of applying the special rates.

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Meters for Open Flow • Chronoflo Telemeters
Propeloflo Meters • Auxiliary Equipment
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VENTURI METER

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of a Venturi Tube installed in the pipe line and a Type M Register, Indicator, Recorder or other instruments connected to the Tube by small pressure pipes. The design of the Herschel Standard Venturi Tube produces a maximum recovery of pressure, thus having the economic advantage of lowering pumping costs.

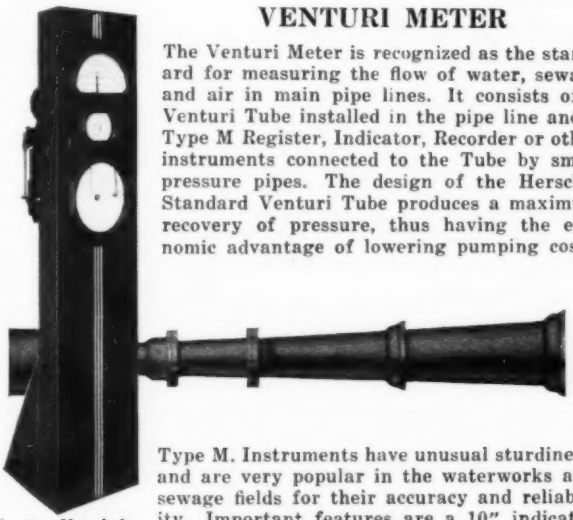

Fig. 1. Herschel Standard Venturi Tube and Type M Register - Indicator-Recorder

Type M. Instruments have unusual sturdiness, and are very popular in the waterworks and sewage fields for their accuracy and reliability. Important features are a 10" indicator at eye level with uniformly spaced scale; improved integrator; 12" uniformly spaced charts; white pyralin dials and interior illumination. This instrument furnishes three kinds of information: continuous indication of the flow; a permanent record on the 12" chart; and the total quantity on a 3½" counter dial. All dials graduated in direct reading units for the particular line being metered.

PROPELOFLO METER

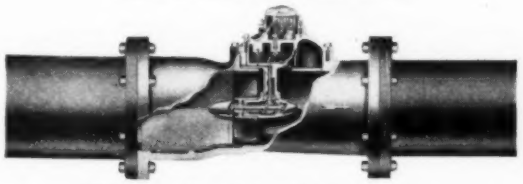

Fig. 2. Propeloflo Meter flange mounted. Available also in bell and spigot model.

This improved, propeller-type flow meter for main water line metering introduces many new features including streamline Venturi design. A self-contained unit easily installed; registers total flow directly in gallons. Accurate throughout wide range; low loss of head; low first cost and upkeep.

FLO-WATCH

A small, medium-priced mechanical instrument which measures the flow of liquids, steam, air and gas through standard differential producers such as Venturi Tubes, Nozzles and Orifice Plates. Also furnished with Kennison Open Flow Nozzles, Parshall Flumes and Weirs or for open channel flow measurement. This sturdy, accurate and dependable instrument is available in a variety of mountings and dial combinations and for remote operation of secondary instruments or the automatic proportional control of dry or liquid chemical feeders. Three separate easy to read dials are compactly arranged in the space usually required for only two dials:

(1) Fast moving, seven-digit cyclometer type Totalizer.
(2) Uniformly spaced 10-inch segmental Indicator.
(3) Uniformly graduated 12-inch Chart Recorder.

FILTER CONTROLLERS

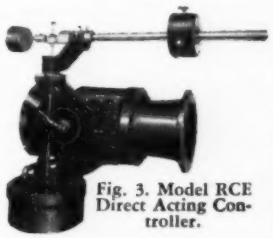

Fig. 3. Model RCE Direct Acting Controller.

Several models are offered, each designed for particular conditions, to automatically maintain constant flow rate through the filter bed. Model RCE features smooth, unwavering control; low loss of head; sturdy, balanced valve; compact flexible design; powerful "floating piston" and exclusive molded tapered piston seal. All rotating bearings anti-friction. Modified for higher pressures and velocities, these controllers serve as Wash Water Controllers or in the effluent lines from pressure filters. Bulletin 321A. Models RCA and RCB are hydraulically operated. Model RCA has a gate type valve with specially shaped seat. Model RCB has a special double butterfly valve of rectangular section and is used for lines over 12" diameter.

FILTER GAUGES

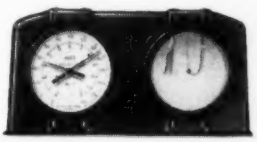

Fig. 4. Loss of Head and Rate of Flow Gauge.

Filter Gauges are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display accurate information gathered by the dependable Builders Diaphragm Pendulum Units. Attractively designed for modern plant interiors. Available in many combinations to indicate and/or record Rate of Flow, Loss of Head, Liquid Level and Sand Expansion. Special types are custom built to engineers' specifications.

METERS FOR OPEN FLOW

Flow through partially filled pipes, sewers and open channels, using a Kennison Nozzle, Parshall Flume, or Weir, where there is a wide range of flow rates, can be accurately measured using standard Builders instruments. The Kennison Nozzle is particularly successful in measurement of raw sewage sludge and trade waste. It is available in sizes from 6" to 36".

CHRONOFLO TELEMETERS

Fig. 5. Chronoflo Receiver.

Chronoflo Telemeters bring to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflo Transmitter.

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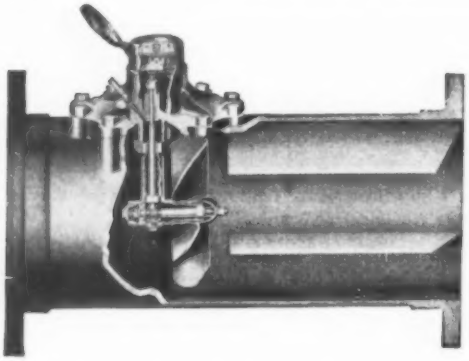


TOTALIZATION is the primary step in all Sparling Main Line Meters. Flow-rate indicators, recorders and controls are added as desired. Accuracy at rated ranges is guaranteed within 2 per cent, and loss of head is negligible!

FLANGED TUBES—2-inch to 36-inch
SCREW TUBES—2-inch to 6-inch
BELL & SPIGOT—4-inch to 36-inch
SADDLE-MOUNTED—6-inch to 72-inch

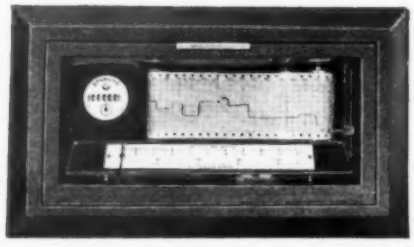
SPARLING Meters are installed as easily as a length of the pipe itself. They can be mounted on the suction or the discharge side of pump.

The Compound meters are installed horizontally, but the tube and saddle type Sparling Meters may be installed horizontally, vertically, or on an angle.

Registration is in any quantity unit desired.

Fire Hydrant Meter

Easily attached to the hydrant and connected to fire hose for accurate measurement of flows from 30 gpm up, with only 1 pound per square inch pressure loss at 200 gpm. Weight, 20 pounds. With Standard Hose Coupling (2½"), $200.

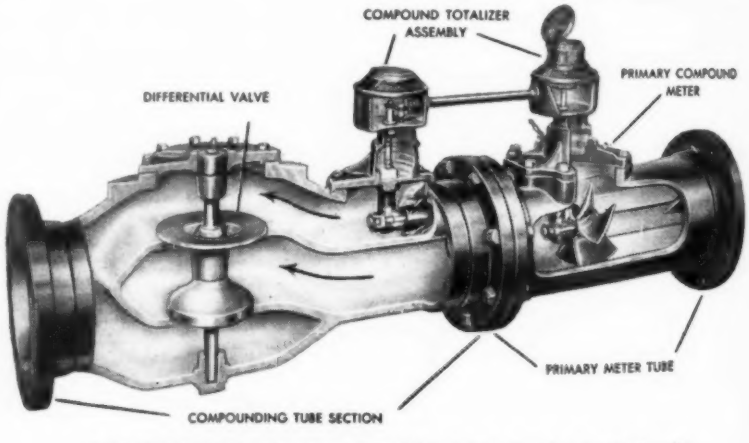


INDICATORS • RECORDERS CONTROLS

Flow-rate indicators and recorders are available for use with Sparling Meters if, as and when required. The mercury-governor type, with circular charts for 24-hour or 7-day records, are mechanically controlled within 15 feet of the meter, or electrically controlled at any distance. They may be Pedestal, Wall or Panel mounted.

The differential type, shown above, has a straight-reading 60-day strip roll chart. Indicator scale is calibrated in two flow equivalents. Operated by electric remote control.

Mechanical or electric controls for autometered chemical feed are available.



COMPOUND Meters for Mains 6-inch to 36-inch

Consistent accuracy over flow-range as wide as 1-to-125

Differential valve cracks at about one pound per square inch back pressure from the smaller meter. The smaller meter measures all flows below the minimum accurate range of the larger meter. Both meters drive through ratchet clutches to a common totalizer, which thus operates with the faster turning meter.

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MAIN-LINE METERING OF WATER, SEWAGE AND SLUDGE

By ROBERT T. REGESTER
Consulting Engineer, Baltimore, Md.

AN accurate and convenient means for metering the flow of water in main pipe lines presented an unsolved problem in early American hydraulic and water supply practice. It was not until 1887 that Clemens Herschel, eminent New England engineer, conceived the idea of applying the Venturi principle as a practical method of flow measurement. After conducting elaborate experiments, he invented and successfully calibrated a compound conical tube which he named the "Venturi meter." In 1891 the meter was first installed by the East Jersey Water Company. Its success was immediate and marked a notable contribution to hydraulic engineering. Twelve years later, the first Venturi meter for the measurement of sewage was installed in a large discharge pipe at the Ward Street Pumping Station of the Boston sewerage system. This installation was also successful and continues in operation today.

Since these first applications, continuous developments and improvements have been made in Venturi metering, particularly with regard to automatic registering and recording instruments. Today Venturi meters and their related devices are used throughout the world in both water works and sewerage systems for a variety of purposes. They are recognized as invaluable aids to the efficient operation and control of modern water purification plants and sewage treatment works. Although other metering elements are available, the Venturi meter is the universal standard for the measurement of water, sewage and sludge flowing through main pipe lines.

Venturi Tubes

A standard Venturi tube, as shown in Figure 1, comprises a cylindrical inlet, a converging inlet cone, an intermediate "throat" section and a diverging outlet cone. The inlet cone has a rather

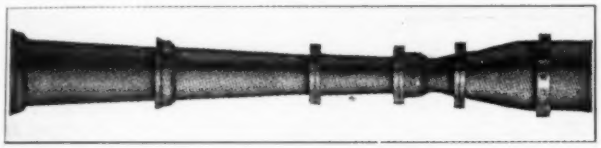

Fig. 1—The Herschel Standard Venturi Tube

steep taper while the outlet cone tapers more gradually. The interior passageway of the tube is entirely unobstructed. The sections of these tubes are usually made of cast iron with throat part bronze-lined to resist corrosion. The inlet and outlet cones are occasionally constructed of either reinforced concrete or steel plates. At both the inlet and the throat of each tube, an annular pressure chamber communicates with the interior by means of numerous small and equally-spaced vent holes. These annual chambers are basically important features of Venturi tubes. The essential purpose of each chamber is to average the pressure head at several points around the tube's circumference, thus avoiding the inaccuracies otherwise introduced by using a single-vent piezometer.

The favorable hydraulic properties of the standard Venturi tube are unequalled by any other type of metering device for main pipe lines. If piezometers are inserted along a standard Venturi tube, the hydraulic grade line will follow the curve as illustrated in Fig. 2. The velocity of flow rapidly accelerates from the inlet to the throat, and thereafter gradually decelerates through the outlet cone. Accordingly the pressure head which is greatest at the inlet end rapidly decreases to the throat where it is least. This difference in pressure bears a definite relation to the velocity of flow and therefore, the quantitative rate of flow. This function varies approximately as the square of the velocity in the throat. It should be particularly noted that the pressure is gradually regained as the velocity decreases in the outlet cone, until at the outlet end nearly all of the original pressure head has been restored. The overall pressure drop, or "friction loss," between the inlet and outlet ends is relatively small for normal rates of discharge, and for low rates it is negligible.

The size of a Venturi tube is expressed by the diameter of the inlet and outlet ends, in inches, which usually is the same nominal diameter as the pipe line for which the tube is intended. The standard tube of Herschel proportions has an average length of about nine inlet diameters, but the exact length depends upon the throat diameter. For installations where the conditions are favorable, shorter and somewhat less costly Venturi tubes are available. In general, these are similar in construction to the standard tubes, but have outlet cones of sharper taper with consequent greater friction loss. Certain special designs of tubes are also made, such as elliptical, constant-acceleration and flat-invert (or eccentric type). In instances where low points cannot be readily drained, or where overhead clearances are very limited, the flat-invert tube may be desirable. However, such tubes are considerably more costly than standard concentric tubes, which experience has demonstrated to be most suitable for normal installations.

For the measurement of sewage and sludge, Venturi tubes require certain special appurtenances. At the inlet and throat pressure chambers, vent-cleaning valves are necessary so that, at intervals, the vents can be cleaned of deposits and the pressure chambers flushed. An individual hand valve is often provided for each vent. However, a recent device (Fig. 3) is available for simultaneously actuating all of the vent-cleaning valves by the operation of a single water- or air-pressure supply valve. Hand holes near the inlet and the throat are useful for an occasional inspection of the interior surface of a tube. In cases where the sewage contains corrosive industrial wastes, a special split-flange section of tube can be provided to expose the entire throat part for examination and cleaning.

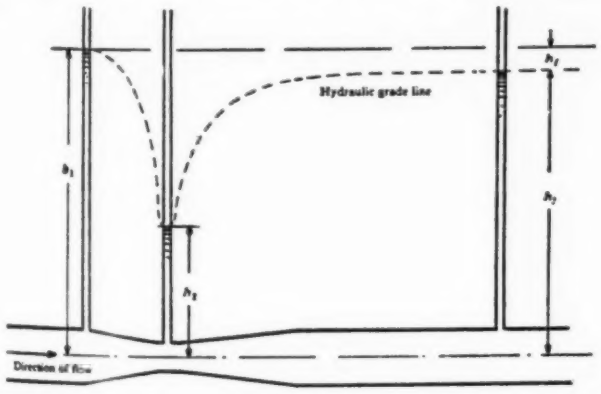

Fig. 2—Hydraulic Grade Line for Flow Through a Venturi Tube

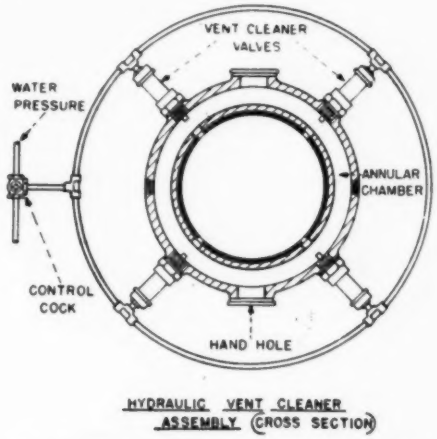

Fig. 3—Hydraulic Vent Cleaning Assembly for Simultaneous Operation

Other Types of Meters

Orifices and Nozzles

Among other types of meters available for main pipe lines are orifices and flow nozzles. Orifices can be obtained in several forms, the most familiar of which is a circular opening in a flat plate clamped between a pair of flanges in the pipe line. The hole of the orifice may be either concentric or eccentric in the flat-plate type. Piezometer connections are made on each side of the orifice plate by tapping two small tubes into the main pipe line. The differential pressure between the inlet and outlet sides of the plate is used to actuate the metering instrument. Orifice plate assemblies with annular pressure chambers, tapped for piezometer connections, are available.

The hydraulic grade line for a plate orifice is shown in Fig. 4. With flow through the main pipe, the pressure head drops abruptly at the orifice and continues to decrease slightly opposite the plane of greatest contraction just downstream from the plate. Beyond this plane the pressure then increases with partial recovery of the original pressure head. Because of the plate projection inside the pipe considerable turbulence results; hence the overall

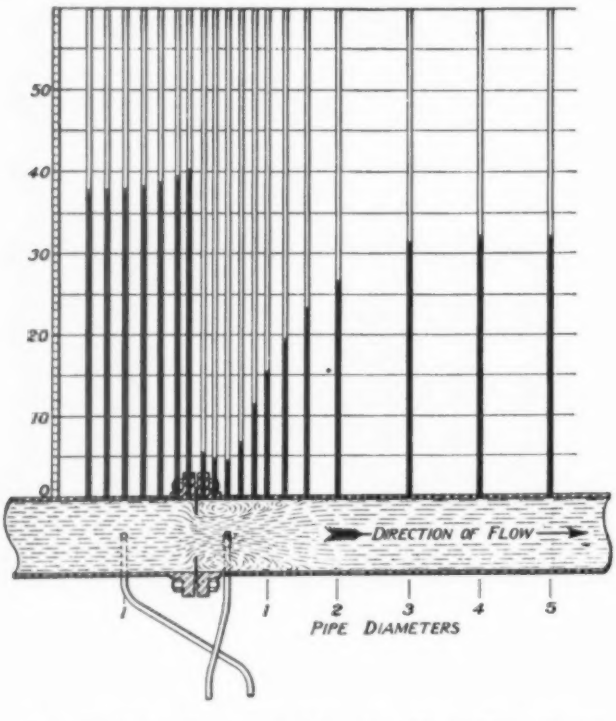

Fig. 4—Hydraulic Grade Line for Flow Through a Contraction Plate Orifice

friction loss for a given ratio of orifice and pipe diameters is much greater than for a Venturi tube having the same ratio of throat and inlet diameters.

If used for the measurement of sewage and sludge, plain orifice meters may be subject to inaccuracies resulting from erosion of the edge and accumulation of solid matter at the projection. Certain specially shaped orifices, or so-called "flow nozzles," resembling Venturi tubes can be furnished to overcome some of the disadvantages of the plate orifice.

The Kennison Nozzle

The Kennison open-flow nozzle is suitable for measuring flows of sewage, industrial wastes and sludge in partially filled pipes and open channels. This nozzle is bolted to the outlet end of a main pipe line with free discharge. The design utilizes the inlet depth produced by a specially shaped outlet for the rate-of-flow function which varies directly with the head. At the inlet of the nozzle, a connection is made to a float tube for operating the metering instrument, Fig. 5. Kennison nozzles are made in inlet sizes varying from 6 in. to 36 in. diameter. Another type of nozzle for partly filled pipes utilizes the discharge-angle relation, produced by a vane which receives the discharge impact, as the rate-of-flow function. This latter nozzle (Schofield) has a parabolic outlet.

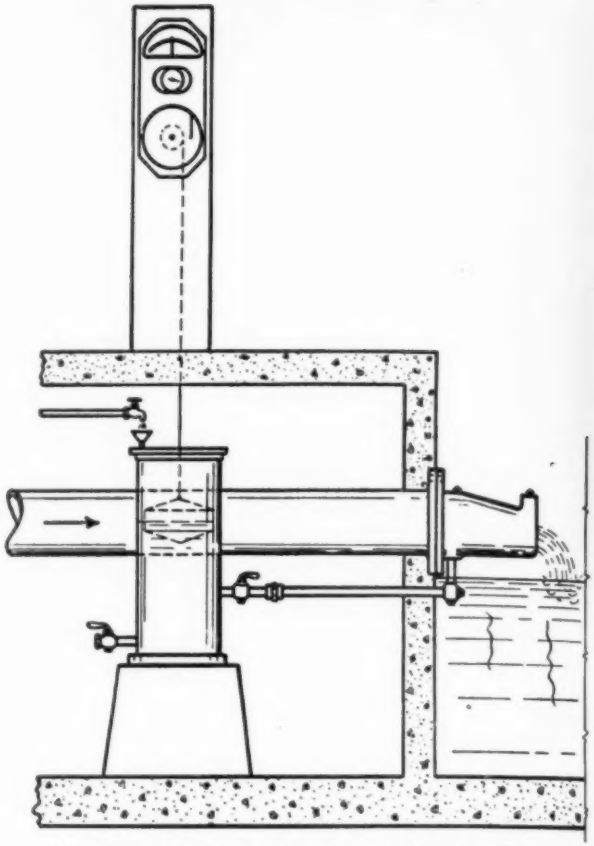

Fig. 5—Typical Installation of the Kennison Nozzle

The Parshall Flume

For the measurement of sewage flows in open channels, the Parshall flume is now extensively used. This Venturi shaped flume usually operates as a free-flow device and therefore requires the use of a single pressure head to accurately determine the discharge rate. The flume was originally developed and is widely used in the West for irrigation purposes. The first important installation for measuring sewage was at Providence, R. I., in 1931, where a large flume having a capacity of 120 m.g.d. with throat width of 10 ft. (Fig. 6) meters the effluent from the sewage treatment plant. An important characteristic of the Parshall flume is the relatively small loss of head, which is about one-fourth that of the standard weir for free flows. This flume is adaptable for both large and small plants and has been calibrated for a variety of sizes and corresponding capacities. A pipe connection is made on the tapering inlet side of the flume for the float actuation of a metering instrument.

Discharge Coefficients and Friction Losses

With any type of meter for main pipe lines, the accuracy of measurements must be supported by exact knowledge of the discharge coefficient and its relation to the size, ratio and other characteristics of the respective type. The accuracy of the Venturi meter has been established through numerous carefully conducted calibration tests by hydraulic laboratories and prominent manufacturers. Such tests have demonstrated that the high initial accuracy of the Venturi meter remains unimpaired during years of continuous service. Coefficient curves for standard Venturi tubes (as made by Builders Iron Foundry and the Simplex Valve & Meter Co.) are available in the A. S. M. E. —Fluid Meters Research Publication, Part I, 1937. In addition thereto, various types of upstream disturbances have been analyzed with regard to Venturi tubes and corrective vanes have been studied by Prof. W. S. Pardoe (Trans. A. S. M. E.—Nov., 1936, and Nov., 1937). Also, a valuable study of the proper application of piezometer connections to metering devices was made by Messrs. Allen and Hooper (Trans. A. S. M. E.—1931) as a further contribution toward meter accuracy.

The overall friction loss produced by a differential metering device in main pipe lines is frequently of economic importance. Such losses may substantially increase annual pumping costs, or may materially decrease the gravity head which is available for

Fig. 6—One-Half of the Parshall Flume, Looking Downstream to Throat Section—Providence, R. I.

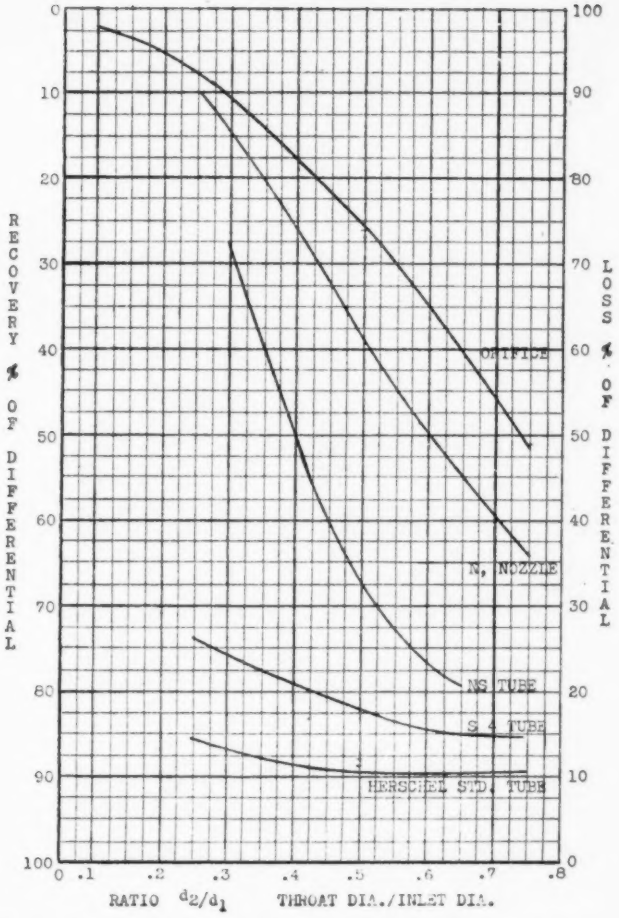

Fig 7—Recovery Characteristics and Friction Losses of Various Differential Producers

For Figs. 8 and 9, see next page.

other essential purposes in both water purification and sewage treatment plants. This latter condition may involve greater construction costs due to the lowering of structures to meet the resulting hydraulic grade lines. In either case, a small initial saving in the price of an unsuitable meter may be insignificant in comparsison with the ultimate cost incurred by excessive fraction loss. Accordingly, that metering device in which the recovery of inlet pressure head is the greatest will most likely prove to be the most economical selection.

The accompanying diagram, Fig. 7, strikingly presents a comparison of the recovery characteristics and friction losses for a standard Venturi tube of Herschel proportions, a short Venturi (S4) tube, two types of flow nozzles (NS and N) and an orifice plate. These data are expressed thereon as precentages of the differential head for various ratios of throat and inlet diameters. For the frequently used ratio—0.5, it should be noted particularly that the corresponding friction loss for an orifice is about seven times the loss for a Herschel standard tube.

Herschel standard Venturi tubes have a friction loss of only 10% to 15% of the differential head for a ratio of 0.25 to 0.75—throat to inlet diameter. In comparison, the fraction loss for orifices is much greater and varies from 49% to 92% of the differential for the same ratio range of orifice opening to pipe diameter.

Venturi Metering Instruments

A variety of instruments for the measurement of water and sewage in connection with Venturi tubes and other differential metering devices is available. Each type is actuated by the differential head, either by direct connection or by some medium of transmission such as air or electricity. Several types of instruments are illustrated in Fig. 8 and 9. The mechanism of one prominent type is shown in Fig. 10. At the rear of the register two large mercury wells, connected at the bottom to form a U-tube, receive the differential pressure from the Venturi

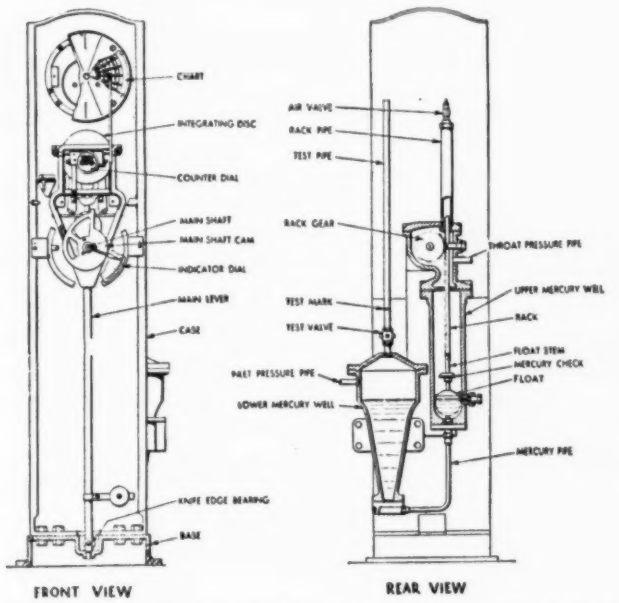

Fig. 10—One Example of the Pressure Chamber Type of Register Mechanism, with Rack and Gear Transmission of the Float Movement

tube through small pipes from the inlet and the throat. One of the mercury columns supports a solid metal float of large diameter, which is responsive to minute variations in mercury levels. Through a positive rack and gear transmission, the float

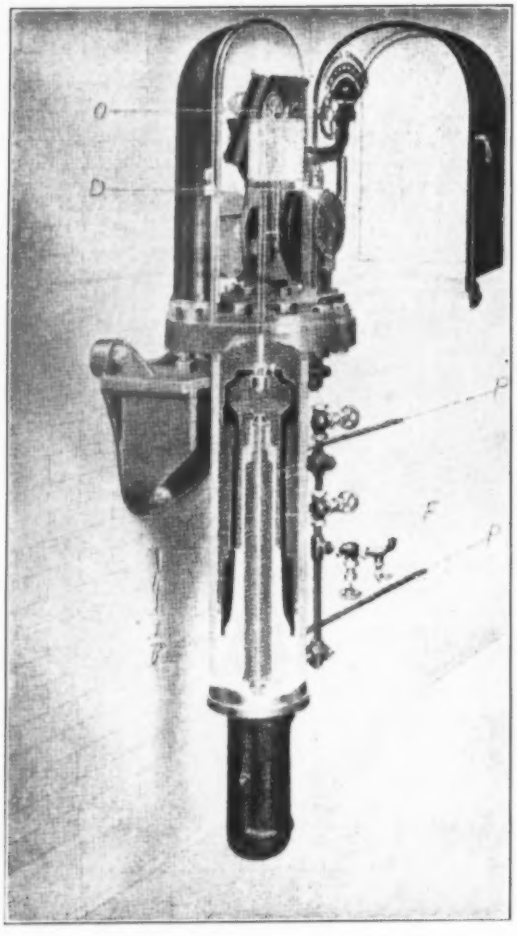

Fig. 8—Pressure Chamber Type of Instrument Using Mercury Sealed Bell (Courtesy of Simplex Valve & Meter Co.)

For Fig. 10, see preceding page.

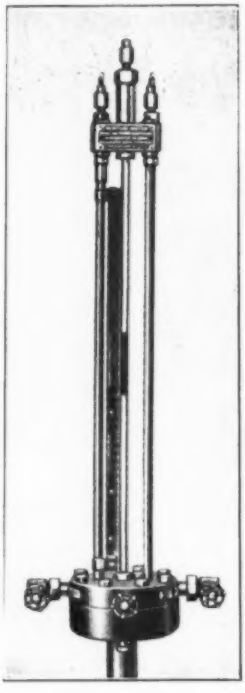

Fig. 11—Portable Flow-Rate Indicating Instrument of the Barometric Type

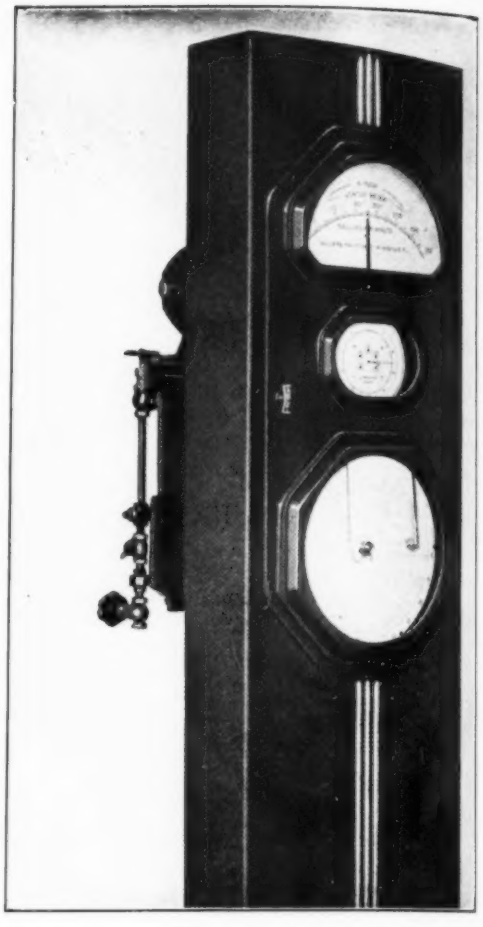

Fig. 9—Modern Register-Indicator-Recorder, with Pair of U-Tube Mercury Wells (Courtesy of Builders Providence)

movement establishes the position of the rate-of-flow indicating hand. the rate recording chart pen and the driving roller of the motor-driven totalizer. These are respectively the upper, lower and middle dials (**Fig. 9**).

A simple mechanical instrument, suitable for main pipes in small plants and for less important pipes in large plants, is very similar to the instrument shown in Fig. 13. This instrument can be used with either Venturi tubes or orifices for the measurement of water, sewage, sludge, air and other fluids. Principal features of this device are compact design, gear-driven integrator and universal mounting for floor, wall or panel.

A portable and sturdy flow-rate indicating instrument of the barometric type is shown in Fig. 11. The rate scale, 22 in. long, can be graduated to read directly in units of flow. The slightest change in rate through the Venturi tube, or other differential producer, will cause an immediate and relatively large response in the vertical movement of the mercury column within the single glass tube. In addition to this instrument, several types of manometers can be obtained for a variety of purposes. A double-tube type is especially suitable for general testing work. Graduations can be either in inches of deflection, or directly in rates of flow.

Where the conditions of installation make the use of mechanically actuated instruments impracticable, electrically-operated transmitters with receiving instruments can be employed for remote metering indications and recordings. Numerous types or systems have been developed such as time impulse, stepped resistance, self-synchronous motor pairs and others.

The time impulse system is used with Chronoflo transmitter and receiver instruments, Fig. 12 and 13. The transmitter receives the differential pressure, and is usually installed close to the Venturi tube or other differential device. It contains a mercury float, a synchronous motor-driven mechanism and a magnetic mercury switch. These elements are so interconnected that for a portion of each cycle (¼ to 1 minute), varying in duration in exact proportion to the rate of flow, electrical "time impulses" are sent to the distant receiving instrument. The latter, through motor-driven magnetic clutch elements, translates these impulses into flow units on the dial and chart.

Weather-proof instruments for installation out of doors are readily available with substantial weather-proof metal housings.

Metering instruments are logical sources of signal and control actions as related to flow rates. Lights, sound apparatus, power relay switches and other electrical elements can be readily actuated by such instruments at relatively small cost.

Methods of Installation

Two simple methods of installing Venturi tubes and instruments for the measurement of water are shown—Fig. 14. That for medium and high heads is on the left, and the method for low heads on the right. When the pressure is ten pounds or

Fig. 12—Transmitting Unit

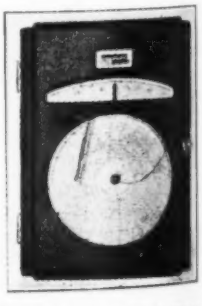

Fig. 13—Receiving Unit

Chronoflo Time-Impulse Instruments for Remote Metering (Courtesy of Builders Providence)

more at the floor where the instrument is located, two small pressure pipes—one from the inlet and the other from the throat of the tube—form a direct connection. These pipes can be several hundred feet in length. Where the acting hydraulic head is low (e.g. raw water supply to filter beds) the usual mercury wells at the back of the registering instrument are

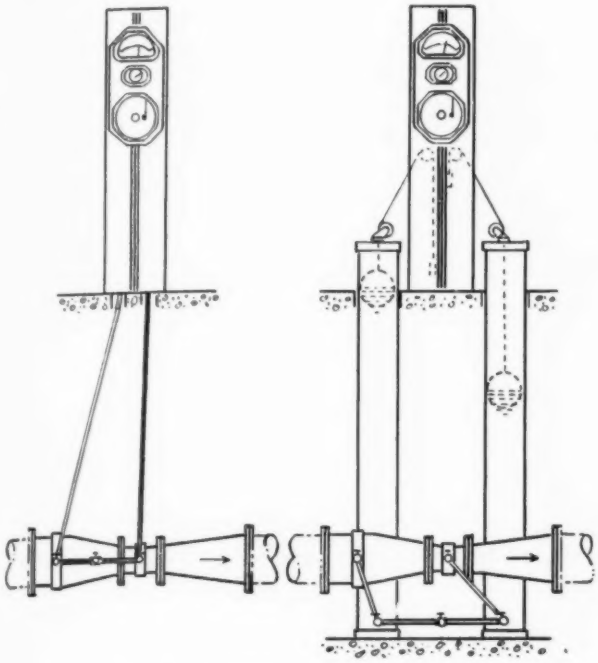

Fig. 14—Venturi Meter Installations
Left—For Medium and High Heads
Right—With Float Tubes for Low Heads

removed and vertical inlet and throat float tubes are substituted. Cables from these floats lead to a differential actuating mechanism at the back of the instrument.

Other types of installation require the mercury wells to be placed at a low elevation with a cable connection to the register above. With any of these types for the measurement of sewage and sludge, provision must be made for seals to prevent deposits from reaching the registering instrument through pressure connections, or for proper flushing with clean water. Such flushing may be either continuous or manually regulated, as the requirements dictate.

Air Relay System

The use of compressed air as a medium for the transmission of the inlet and throat pressures of a Venturi tube, or other differential producer, to a distant recording instrument is frequently advantageous. One type of "air relay system" employs two diaphragm units, one directly connected to the inlet and the other to the throat of the Venturi tube. Each unit consists (Fig. 15) of a hollow chamber (C) which is divided into two compartments by a solid rubber and fabric diaphragm (D). The inner side of the diaphragm is subjected to the liquid pressure from the tube; the outer side receives an external air pressure to balance the liquid pressure on the inner side. Air is continually vented through a throttled needle valve (N) attached to the diaphragm unit. Two small pipes, one from the inlet and the other from the throat relay unit, are connected from the outer compartments to the usual mercury wells at the rear of the registering instrument. The transmitted air pressures are exactly equal, respectively, to the actual inlet and throat pressure heads in the Venturi tube.

This type of unit forms a seal between the tube and the instrument, which is especially important in metering sewage and sludge. In the measurement of sludge, unless it is "thin," it is necessary to provide continuous water flushing through appropriate small sight-feed orifices.

Another well known type of air relay system operates with a single air pressure which is proportional to the amount of the liquid differential pressure.

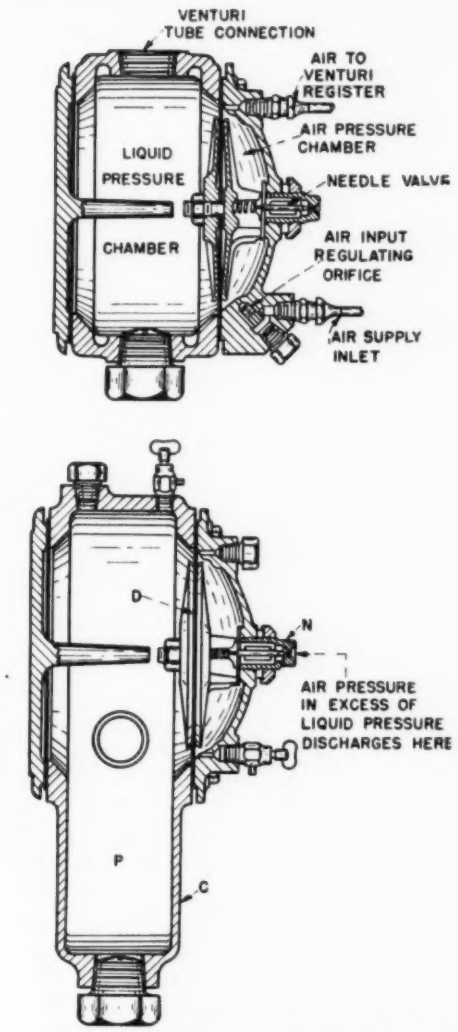

Fig. 15—Diaphragm Unit for Air-Relay System

Flow Summation

Recent developments make it possible to summarize, on a single instrument, the readings of several meters. For example, a water works pumping station may have several pumps with individual meters in their respective discharge pipes. It may be desirable to totalize these separate flow rates for purposes of accurately introducing chemicals, such as chlorine, without wastage. In this case, an electrical transmitter (such as Chronoflo) can be attached to each registering instrument (Fig. 16). The impulses sent out by these transmitters go to a master unit which integrates the respective values, and then transmits the total to distant summation indicating, recording and totalizing instruments, as required.

In sewerage districts and sewage treatment plants, the summation principle can be utilized to great advantage. Sewage flows from scattered communities can be summarized and transmitted to the central or joint treatment plant for the guidance of the operator, and for the allocation of operating charges. Likewise, flow divisions within a large sewage plant can be summarized for control purposes.

Means can also be provided to give the difference in readings for two meters, or the difference of the combined rates of flow in groups of meters.

Special Metering Instruments

The marked trend in recent years of centralized control in water purification and sewage treatment has been accompanied by a fulfilled demand for the broader performance of main pipeline meters. Distant transmission by air or electricity to centralized panels and control tables, the ratio of one flow to another, the summation of flows to one or more central dials, the automatic

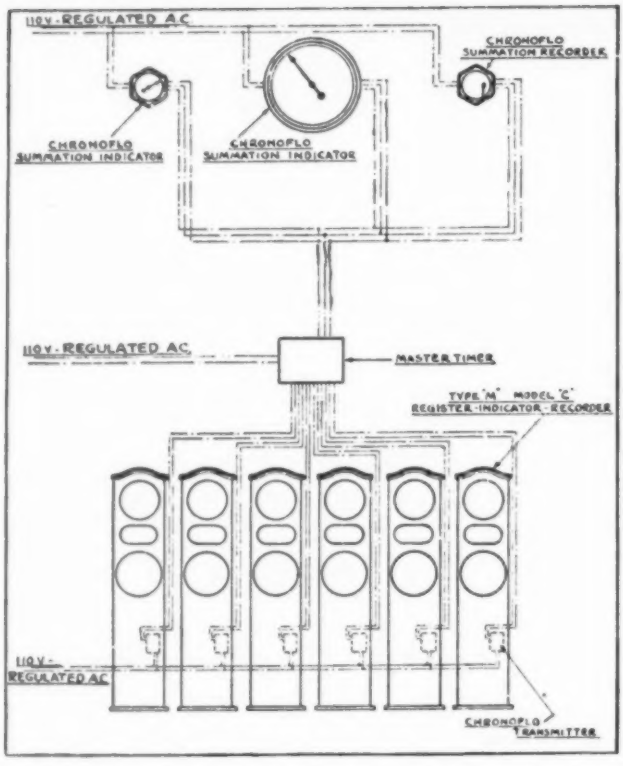

Fig. 16—Diagrammatic Arrangement of Flow Summation Instruments for Cermak Station, Chicago

controls of flows and distant pumps to maintain perdetermined levels or rates, the proportioning of chemical dosages to main flows and other functions, are examples of modern metering requirements. The design and finish of the instruments themselves have been "modernized" to harmonize with the present architectural attractiveness of plant interiors. Effective illumination has been likewise provided for single- and double-faced master indicating gauges, frequently of large diameter.

A flow and ratio gauge for each unit in a modern activiated sludge plant is illustrated, Fig. 17. There are five dials, the three largest showing (left to right) rates of air flow, sewage flow and return sludge flow to an aeration tank. The two smaller dials show (left) the ratio of air to sewage—in cu. ft. per gal., and (right) the ratio of return sludge to sewage—in per cent of sewage flow. In addition, there is an automatic control knob for pre-setting the latter ratio for any desired value. A pair of these five-dial gauges are mounted on one control table similar to those used in water filter plants.

Installation Requirements

To insure the proper application of metering equipment, specific data should always be obtained from the meter manufacturer for a particular installation. However, in general, certain standard requirements are noteworthy.

The Venturi tube should preferably be preceded by a straight length of pipe having the same diameter as the tube; this length being at least six times the tube diameter up to 24 in. and at least 12 ft. for larger sizes. Where space is limited, or there is the probability of turbulent or spiral flow ahead of the tube, straightening vanes may be required. Any kind of fitting may be placed at the outlet end of the tube. Since the centrifugal pump is almost universally used in water works and sewerage systems, pulsations in flow are rarely encountered. However, such condition may occasionally be presented and must receive special consideration. It is essential in making pressure pipe connections that they be run on a continuous grade, avoiding summits or depressions where air or silt may collect.

The Parshall flume must be set at the proper elevation with respect to the channel, preferably so that it can operate at all times under "free flow" conditions, with a limit of 95% submergence. It should be located in a reasonably straight section of channel, where the distribution of flow is fairly uniform. The flume, however, will operate satisfactorily under rather poor approach conditions. The dimensions and proportions of the flume must adhere to the established standards.

In installing the Kennison nozzle, care must be taken to provide proper approach conditions. This device should be preceded by a section of pipe at least eight diameters in length, and the water or sewage must flow smoothly from the nozzle under free discharge. Any conditions of installation which might cause a "shooting velocity" at times, should be corrected by the use of proper fittings upstream.

Orifice plates are more sensitive to approach conditions than Venturi tubes, and require a straight length of smooth pipe both upstream and downstream from the plate. For the upstream, the length required may vary from five to thirty diameters, while for the downstream length—up to eight diameters, depending upon the piping layout and the diameter ratio. Straightening vanes may be required to eliminate swirls, cross currents and eddies; their use may make it possible to shorten the necessary lengths of pipe as just mentioned.

Conclusion

Certain fundamentals of main line metering and some of the modern developments in metering equipment have been briefly discussed. Emphasis is placed upon the importance of regarding each meter installation as an engineering problem, which requires the consideration and advice of experienced manufacturers. Low cost equipment may properly serve for relatively unimportant work, but is entirely unsuitable for checking the daily performance of main units and for controlling the efficiency of treatment processes. In general, the highest grade of equipment as offered by prominent manufacturers cost only a small fraction of the total construction contract on important projects. Obviously, the best is the wisest selection.

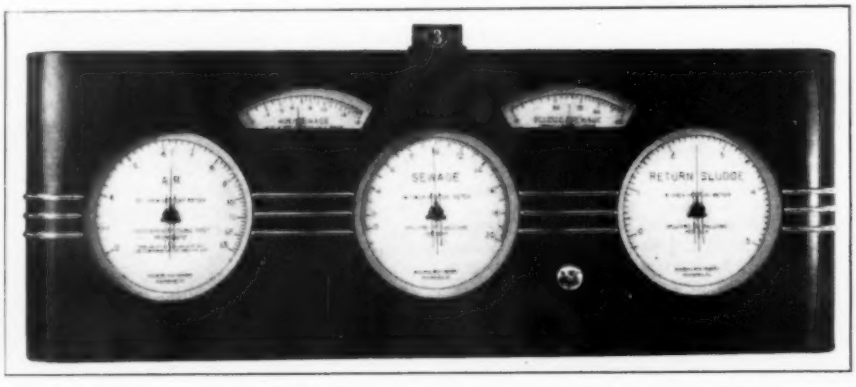

Fig. 17—Special Flow and Ratio Gauge for Modern Activated Sludge Plant, Baltimore, Md.

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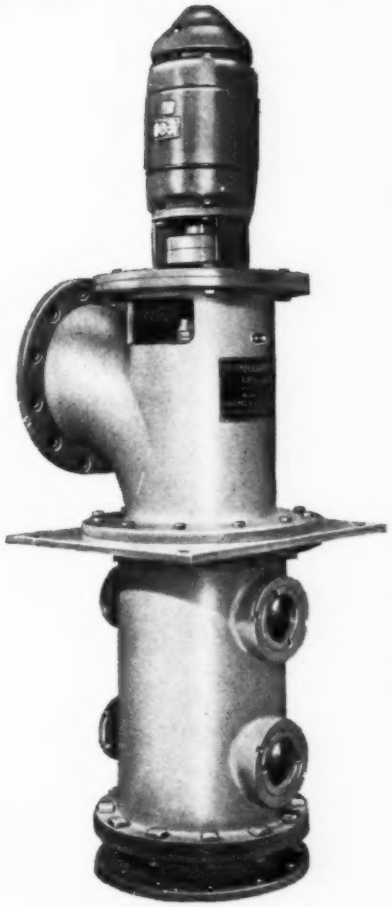

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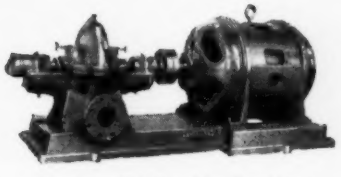
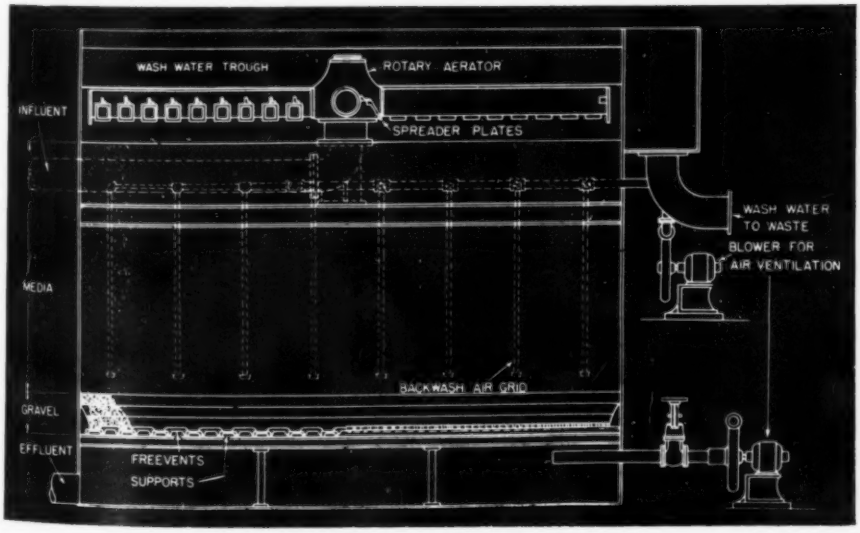


Horizontal Double Suction



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CENTRIFUGAL PUMP PECULIARITIES

By ROBERT W. ANGUS
Consulting Engineer, Toronto, Ont.

PRACTICALLY all pumping units now being installed in water works plants are composed of centrifugal pumps driven by electric motors, steam turbines or internal combustion engines, and few plants today use reciprocating pumps. Experience with centrifugal pumps has now been sufficiently extensive for operators to know many of their peculiarities; yet there are features connected with their use that are worthy of review.

Setting of Pump

The setting of the pump is perhaps one of the most important matters, as it may easily account for any later defective operation. It is, of course, well known that the pump should be set as little above the well level as possible, and it is usually preferable to have it below this level (except for the difficulty of unwatering it) if for no better reason than ease of priming and freedom from the foot valves on the suction line. That the pump is unduly sensitive to suction conditions is a matter of general experience, and long and crooked suction piping is to be avoided.

The author has made tests on the effect of foot valves, which showed that resistance in these might cause a high vacuum at the suction flange of the pump and a corresponding decrease in discharge. [*Jour. AWWA*, **37**:70 (1945)]. High-suction vacuum naturally induces air leakage into the pump through the glands, and also releases whatever air there is in the water being pumped. In order to investigate the effect of air leakage, a number of experiments were run on a 4-in. pump, in which various volumes of air were admitted into the suction pipe after carefully sealing the glands so that leakage was practically stopped there.

In this pump the percentage decrease in discharge at a given head was roughly proportional to the percentage, by volume, of air admitted, so long as the latter remained below about 1.5 per cent (see Fig. 1); but thereafter the water discharge fell off very rapidly until there was a decreased discharge of over 40 per cent when 4 per cent of air, by volume, was admitted. This merely confirms the well-known fact that at low suction lifts, and consequently low air inlet leakage, the exact elevation of the pump is not so important. There is a critical elevation for each pump and condition, however, and if this is exceeded the loss of water increases at a rapid rate. Clearly the height of the pump above the well level should be kept substantially below this critical elevation.

Specific Speed

Fortunately the importance of this matter is now recognized by the pump builders, and they have found that for each head, discharge and speed there is a maximum height above the well at which each pump should be set. These three quantities are combined in a formula for "specific speed" which is defined by:

$$\text{Specific speed} \quad N_s = \frac{N\sqrt{G}}{H^{0.75}}$$

where N is the revolutions per minute, G is the discharge in U. S. gallons per minute and H is the head in feet.

Pump builders have co-operated in connecting the specific speed and head with the maximum allowable suction lift, basing their conclusions on laboratory tests and on experience with pumps which they have installed. Through the Hydraulic Institute they have given these maximum elevations in the form of diagrams, separate ones being used for single-entry pumps, for double-suction single-stage pumps, etc.

As an illustration, there are four double-suction single-stage raw water pumps at the Victoria Park pumping station, Toronto, Ont., rated at 24, 30, 48 and 60 mgd., respectively, all of them for 9-ft. suction lift and for a total head of 82 ft. The two larger pumps operate at 750 rpm., and if this speed had been adopted for all four pumps, their specific speeds and maximum suction lifts, including velocity head and friction in the suction pipe, would have been as shown below in the Institute's chart.

Size of pump, mgd. (U. S.)	24	30	48	60
Specific speed at 750 rpm	3545	3970	5010	5610
Maximum allowable suction lift, *ft*	18	15	5	..
Necessary suction pressure, *ft*	..	..	..	5
Specific speed at 500 rpm	..	..	3340	3749
Maximum allowable suction lift, *ft*	..	..	20	17

Since the velocity heads in the two larger pumps are 2.3 and 2.1 ft., respectively, and since friction must be allowed for, it is clear that, while there is a margin on the two smaller pumps when run at 750 rpm., the two largest pumps could not be run at this speed and had to be changed to 500 rpm., which is the next available speed.

Setting pumps too high not only causes them to lose capacity, but also means noisy operation and cavitation, which is frequently destructive. As the capacity of a pump at fixed speed is gradually increased by lowering the discharge pressure, a point is finally reached where the characteristic curve is nearly vertical, which point naturally corresponds to the limiting output of the pump. Cavitation and noise are present at such a discharge (and in its vicinity) and the higher the suction lift the lower this limiting output is. It is to avoid too close an approach to this point that the charts reproduced have been made. Noise in a pump operating near this limiting point may often be stopped by the admission of a very small volume of air to the suction pipe.

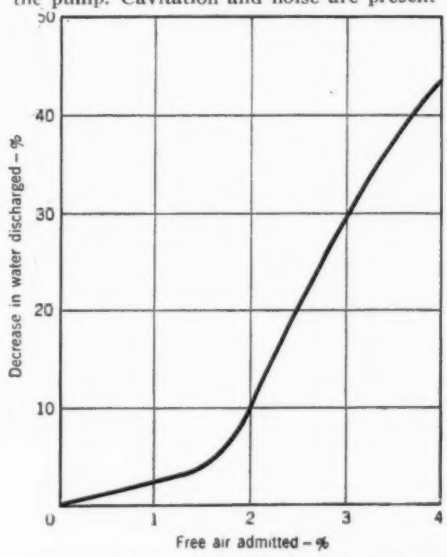

Fig. 1—Decrease in Discharge of Centrifugal Pump Due to Admission of Air Into Suction Pipe in Various Amounts.

[Ed. Note—Indeed an interesting and illuminating statement in view of the generally held misconception that cavitation, with its noise of pebbles or buckshot passing through the centrifugal casing, is due to air within the casing. On the contrary, it appears that the noise is due to partial vacuum within the casing which is relieved by admitting air.]

Power Failures and Water Hammer

Power failures on motor-driven centrifugal pumps present some problems. A check valve is usually placed on the line close to the pump, and if this acts slowly there is backward flow through the pump which reverses its direction of rotation unless specially prevented. If the check valve does act rapidly, however, water-hammer pressures are often excessive, resulting in damage to the plant. A number of cases of the latter have recently come to the author's attention.

Water hammer, contrary to a common belief, is also often dangerous in low-head pumping. The author made some tests on a 12-in. pump working against a 55-ft. static head, with a discharge line only about 350 ft. long, and recorded the pressures with a Crosby indicator with a 30-lb. spring. When the switch was opened the pressure drove the indicator pencil off the top of the drum, indicating a pressure of more than 60 psi., and the first pressure wave measurable showed 50 psi. or a 115-ft. rise. As stated, this was a short line and the pipe velocity was under 4 fps. However, in another case where the static head was 40 ft. and the line was over 2,000 ft. long, the pressure rose to 83 ft. with normal pipe velocity of slightly over 7 fps. In both cases the pressure rise was high enough to cause some anxiety, which was further aggravated in the first case by the noise and shock plainly observed at the pump, while in the second case there was *no* apparent shock on the system. In the first case, the maximum pressure rise occurred 2.6 seconds after cutting off the power, whereas it took 13.0 seconds in the latter case.

Short lines are sometimes more dangerous than long ones, because in the latter the water takes an appreciable time to slow down before coming backward, thereby giving the check valve time to close *gradually* and prevent any real reverse flow of the column. In short runs of pipe the water column reverses in much less time, as the above measurements show, and

actually *before* the check valve has had time to close. Thus the water gains a high backward velocity, suddenly closing the check valve with a slam, and producing high pressures. The maximum pressure rise, in feet, reaches about one hundred times the velocity of the water in the pipe at the time the valve suddenly closes.

Air Chambers vs. Properly Closing Check Valves

Sometimes an effort is made to decrease the danger by using an air chamber, but this is far from the best method and does little good unless the chamber is placed on the line near the pump and has a large short connection with the pipe. Air chambers connected to the line with a fairly long branch pipe are of little value and, of course, any virtue the device has will be lost unless there is a good volume of air in the chamber under normal conditions. A well-designed check valve, with a proper controlling mechanism which permits the greater part of the closure to be rapid and the latter part gradual, offers a good solution, and a number of such valves are now on the market. It is a fact that unless the pump is equipped with a heavy flywheel, as is sometimes the case, the pump will often run backward before the check valve closes, but, in general, the reverse speed is not over 20 per cent higher than normal running speed and is not dangerous from that standpoint.

In many installations reverse rotation of the unit causes little difficulty, but where sleeves are screwed on the shaft and pass through the packing gland, the builder usually makes the thread so that during pumping the tendency is to tighten the sleeve against the impeller. If the glands are tight, then when the pump runs backward the sleeves may unscrew, and cases are not unknown where the pump has been damaged by breaking off the bearing bracket. With the sleeve unscrewed the impeller is not properly restrained from moving along the shaft and this further increases the danger of damage.

Pumping Plants

There are some unusual installations, one of which may be mentioned as an illustration (see Fig. 2). A very large size pump with a vertical shaft was set up with 40 ft. of vertical discharge pipe followed by a long horizontal line. The pump was nearly 20 ft. below the water in the well so that no priming was required, but there were nearly 800 ft. of horizontal suction (intake) pipe in which the velocity was 5.9 fps. at steady operation. It was inconvenient to place the discharge valve close to the pump, and it was actually installed just beyond where the horizontal and vertical pipes joined. There was no valve of any kind on the suction side. In the installation shown diagrammatically in Fig. 2 the distance (A) was nearly 20 ft.

Following common practice, the motor switch was thrown in with the discharge valve closed, and just as the valve started to open when the pump was up to speed, a pressure shock cracked the pump casing. This might have been foreseen, because, when the pump was shut down with discharge valve closed, water in the vertical discharge pipe quickly fell to the well level, leaving a space filled with air in the discharge line between the well level and the valve. On starting the pump against the closed valve the air was compressed to about discharge pressure, and as the valve

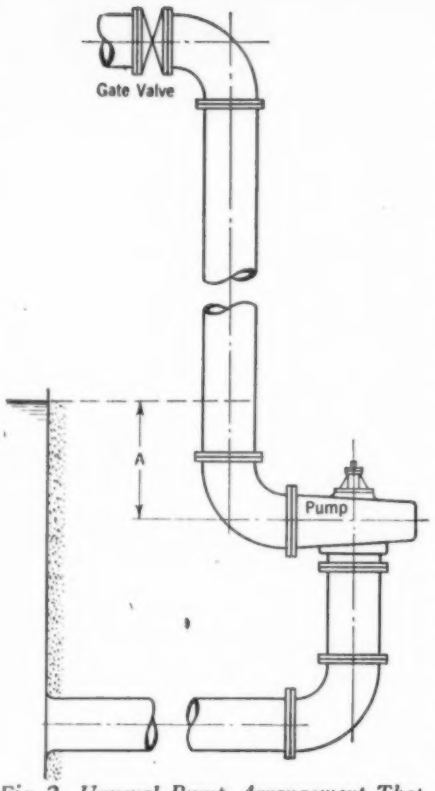

Fig. 2—Unusual Pump Arrangement That Resulted in Heavy Water Hammer Pressures Until Vacuum Pump Was Installed to Exhaust Air from Discharge Pipe and Fill It with Water Before Starting Up.

began to open the air rushed out of line, allowing the water to reach full velocity in the vertical pipe. As the front of this water column reached the partly open valve the velocity was largely extinguished and a heavy water hammer pressure resulted. Since it would have been very expensive to lower the discharge valve, the only remedy was to put in a vacuum pump and exhaust the air, in order to fill the line with water before starting up.

The long horizontal suction pipe greatly complicated the problem, for the water would be drawn from the pump end of it before the column could be sufficiently accelerated to supply the demand, and water hammer pressures would be set up in the pump from this cause. A well should always be close to the pump (or the pump located close to the well) to supply the water demanded while that in the intake line is being brought up to running velocity.

Where several pumps are to work in parallel on the same line, their characteristics should be given careful consideration, otherwise their actual output may fall far short of the sum of their individual deliveries. In Fig. 3 are shown the characteristic curves of two actual pumps, A and B, in the same station, their individual normal operating points being indicated by G and J. If these two pumps are thrown on the line at one time their combined characteristic is shown by the plain curve found by adding the discharges of A and B at the same pressure in each case. The static head, corresponding to the tank level, is shown at D, and the curve C indicates the dynamic head to be pumped against, the vertical distance between D and C corresponding to the resistance loss for the corresponding discharge.

It is to be noted that, while the sum of the separate discharges at rated heads is 180 per cent of the discharge of the larger pump, yet when both are put on the line at the same time the combined discharge at F is only 133 per cent of that of the larger pump, because of the increased pressure. Where the individual characteristic curves are flat this decrease is greater than with steep curves, because a slight increase in pressure corresponds to a large decrease in discharge, but, on the other hand, a pump with steep characteristic at the normal output point has a rapid decrease in pressure for discharge above normal, so that other circumstances must be taken into account.

Propeller-type Pumps For Low Head Duty

Propeller-type pumps are being introduced to a fairly large extent to cover the field where the head is low and the discharge is large. Centrifugal pumps are used in this service, but must be run at slow speed and involve the use of a speed reducer or an expensive and bulky motor, whereas the propeller-type pump is relatively small and may be run at the speed of the ordinary motor. Its field of service is for drainage and sewage work and for pumping water up to water works filters, but the same type of pump is also used for deep wells because its small diameter enables it to be fitted inside ordinary pipe casing.

As so far developed, these pumps have the undesirable characteristic forms of curves, where the head and power at zero discharge and at full speed are higher than, and sometimes twice as high as, the corresponding quantities at rated discharge, and the curves generally have the reversed form. Usually the pressure is not high enough to cause any trouble, but the high power means a correspondingly large torque on the motor, which the latter may not be able to produce. Therefore either special starting devices are necessary or the pump must not be brought up to speed with a closed discharge valve. With a check valve on the discharge and an open gate valve, the head developed cannot exceed the back pressure from the line, and this is one effective method of starting that is used. Also a bypass is sometimes arranged around the pump, having a valve which may be opened so as to allow some water to flow through the pump, thus avoiding the zero discharge condition.

Deep Well Pumps

Deep well pumps must be as small in diameter as possible so that they will fit into the well casing, and for that reason they approach the axial-flow type with relatively small head per stage, although the high motor speeds somewhat compensate for this. However, for the higher heads many stages are used, and guide vanes are placed between each pair of impellers. Both open and closed impellers are used, but the latter are the more common. The driving motor is often placed at ground level, and the pump is usually submerged in the well water to avoid priming, but since these wells are sometimes 200 ft. deep, the driving shaft is long and has to be guided at various points at which rubber-lined guide bearings are often used with water lubrication.

Some builders, such as Byron Jackson, couple the motor to the shaft as in ordinary installations, and the motor is there-

fore submerged in the well water and often is actually located *below* the pump.

Power failures on these pumps, where the vertical pipe is long, result in back-flow through the pump and cause the pump to run in the reverse direction, but most pumps of this type are designed to withstand this without damage. However, the surges in the pipe during reverse flow of the water affect the pressures in the pump to such a degree that open impellers may be forced to pound down against the casing and wear somewhat rapidly. Some builders arrange a ratchet or a brake on the pump shaft to prevent the latter from turning backwards.

Where both motor and pump are submerged and completely enclosed, it is difficult to tell whether the electrical connections are such that the pump is running backwards, and in three-phase circuits it is well known that the connection for forward rotation can only be found by trial. If it is impossible to tell by visual inspection whether the pump runs backwards or not, about all that can be done is to read the discharge gage pressure; if this pressure at no discharge is very much below the normal working head on the pump, the motor and pump are, in all probability, running backwards.

Miscellany and Summary

Noise accompanied by cavitation damage in pumps is frequent if the pumps are set high above intake water level. The same results are noticed when the discharge is low, due to either reduced speed or increased head. Foot valves and strainers on the suction inlets may also induce these troubles and should be avoided where possible.

Occasionally cavitation has seriously damaged impellers in less than two years but it is often quite possible to build up the damaged places and completely restore delivery and efficiency. Frequent inspection is necessary. In one case an impeller was covered with a thick coating of slimy material which decreased the capacity considerably. This pump was used partly for refilling the coagulating basins and was designed for about a 26-ft. head. When the water was low in the well its capacity fell off. A number of operators have found that high suction lift decreases output.

Occasionally, noise in the motor gives the impression that the pump is at fault.

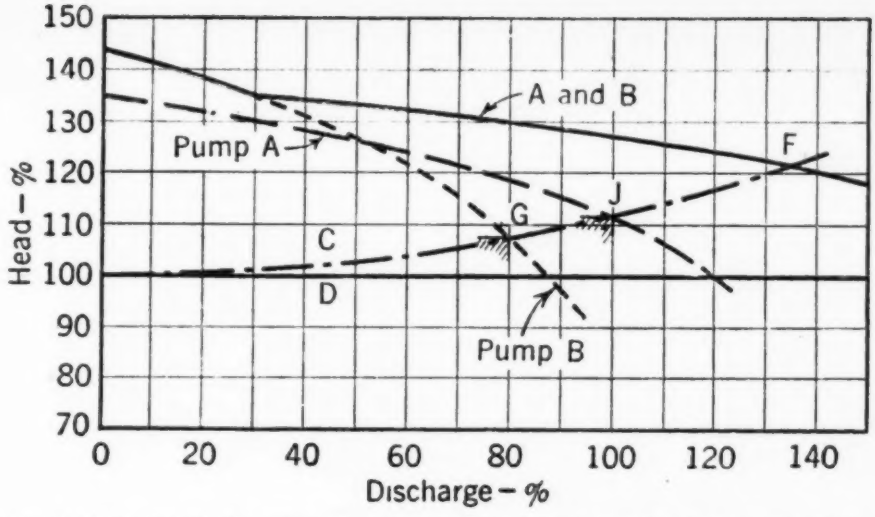

Fig. 3—Characteristic Curves of Two Pumps Operating in Parallel in the Same Station and Discharging Through a Common Header.

Noise in the pump may frequently be greatly reduced by admitting air to the suction side, but this must be carefully controlled, as the capacity falls off rapidly as the admitted air increases. In some tests of one pump 4 per cent of air by volume reduced the capacity nearly 40 per cent.

Putting several pumps in parallel on the same line decreases the capacity of each in a way that varies with the pump characteristics. There is, of course, increased friction in the discharge lines when more water is put through; and, as this increases the head on the pump, there will be a corresponding decrease in discharge.

There is an objection to a common suction header for several pumps, as air may leak through the glands on the idle pumps and interfere with those running. The suction pipe of each pump should run direct to the well as an independent line.

Water hammer and pressure surges are common on lines having centrifugal pumps. Frequently a pressure surge lasting a short time occurs when a pump is put into service. Power failures cause extensive pressure oscillations which have been greatly reduced by special types of check valves with a controlled time of closure. Air chambers are not as satisfactory.

The shape of the profile of the discharge main greatly affects water hammer in the line after power failure. In the 48-in. line in Toronto there is a point where the pressure drops much below atmospheric when power fails, and observations agree with the theory that the water column actually separates at this point. The use of a specially controlled check valve with 4-in. bypass has prevented a dangerous pressure rise when the columns re-unite; the purpose of the bypass is to fill enough of the space with water before the velocity of the returning column from the reservoir becomes high enough to cause damage when it re-unites with the part of the column at the pump end. The actual maximum pressure rise is only about 35 per cent and is reached in about 50 seconds where the pipe velocity is low. The pump is about 4,300 ft. from the breaking point of the column and nearly 8 mi. from the reservoir.

Reversal of pumps after power failure has often been observed, but with no harmful results to the motors. A case has been reported, however, of an engine driving a centrifugal pump being damaged by running backward.

Aside from ordinary wear, the mechanical difficulties with pumps are not serious. Some pumps have excessive end thrust, and where this is taken up by ball bearings, the latter run hot. Over-lubrication is known to increase the heating. Bearings are easily cooled with a small stream of water. Hydraulic balancing of end thrust is satisfactory where the pump is running under normal conditions.

HOW TO BEND PIPES

TO bend steel pipes, fill with dry sand and plug the ends. Heat to a red heat in the localities to be bent and then bend. *Be sure that the sand is dry.* Where bends are slight, it is often unnecessary to use sand. The object of sand is simply to keep the sides of the pipe from collapsing, or to prevent reduction of flow area. If wet sand is used, and if the ends are plugged, the pipe may burst when heated, due to the steam pressure generated.

For the smaller pipes instead of sand resin is good. There is, however, a "right way" and possibly several wrong ways to use resin. An example of a wrong way was recently brought to my attention where the mechanic filled the pipe with resin, plugged the ends, and heated the pipe at the place where he wanted to bend it. He watched for a "red heat" just as he would had he filled the pipe with sand. The result was a violent explosion.

To use resin correctly, pour it into the pipe molten and allow it to cool and harden. As soon as the resin is hard, bend the pipe cold. Don't heat it. Then after the pipe is bent, heat the pipe all over sufficiently to melt and remove the resin.

Equal results may be secured by using lead instead of resin. I have been told that on cold days water has been used also.

Many excellent mechanical devices are on the market for bending pipe. To bend large, stiff pipe slightly (and inexpensively), there is nothing handier or more efficient, in my judgment, than a hydraulic pipe bender driven by a hand pump.

THE Atlas Mineral PRODUCTS COMPANY OF PENNA.

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Tegul-MINERALEAD JOINTING COMPOUND

FOR BELL & SPIGOT WATER MAIN

Tegul-MINERALEAD is a radically different jointing compound with advantages not matched in total in any other product for its purpose. Its sulphur base includes, as a plasticising agent, a special olefine polysulphide which contributes these advantageous properties: GREATER ADHESION TO METALLIC AND CERAMIC SURFACES • HIGHER RESISTANCE TO VIBRATION and to MECHANICAL SHOCK AND TEMPERATURE CHANGES • GREATER PLASTICITY and LOWER COEFFICIENT OF EXPANSION.

Using *Tegul*-MINERALEAD you may expect:

SPEED — *Tegul*-MINERALEAD melts, pours and sets quickly and uniformly (a factor in reducing labor costs). Joints show less than usual initial leakage and backfilling may start at once, thus hastening removal of traffic hazards which arise from open trenches.

CONVENIENCE — Molded in 10 lb. ingots, *Tegul*-MINERALEAD is easier to handle, ship and store. The ingot is impervious to moisture so may be stored outdoors in any weather. Since there can be no change of composition in an ingot, *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our factory.

ECONOMY — *Tegul*-MINERALEAD weighs only 1/5th as much as lead (and goes 3 times as far) saving in shipping costs. 5 ingots to carton makes a handy package. It needs no caulking or deep bell holes and requires no skilled labor. The sum of *Tegul*-MINERALEAD'S advantages make it a *money-saver*, too.

RESISTANCE TO SHOCK — Higher resistance to mechanical and thermal shock promises permanently tight joints. Lines laid with *Tegul*-MINERALEAD in every kind of terrain and meeting every kind of punishment, have served for years without need of attention.

AVAILABILITY — *Tegul*-MINERALEAD is stocked at conveniently located points and is usually available on short notice. Using *Tegul*-MINERALEAD helps conserve lead, a scarce material.

HOW *Tegul*-MINERALEAD IS USED

MELTING — *Tegul*-MINERALEAD melts at 248°F., requiring only a slow fire. Care should be taken to avoid direct contact with flame and overheating, which tends to cause the compound to thicken. Best results are had by using furnace designed by the manufacturers of *Tegul*-MINERALEAD.

YARNING — The pipe at Bell and Spigot must be clean and free from accumulations of oil, tar and grease. If jute is employed it should be the dry, braided type.

POURING — See that joints are clean. Use mud on asbestos runner to prevent adhesion to the *Tegul*-MINERALEAD and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or pouring pot of sufficient capacity to fill the joint at one operation. Add whole or half ingots to replace *Tegul*-MINERALEAD used. It is not necessary to wait for complete melting before pouring more joints. Cut off pouring gate when compound has solidified. Remove runner and joint is complete.

G-K The *Original* Bituminous SEWER JOINT COMPOUND

For Vitrified Tile and Concrete Sewer Pipe

Positive, Pliable and Permanent as vitrified tile itself. Never becomes brittle. Always retains flexibility. Needs no skilled labor. Can be used in winter temperatures. By preventing infiltration of ground water, G-K makes subdrains unnecessary. Completely fills annular space between bell and spigot. Standard package 170 lbs.

The HYDE-RO Ring

AN IMPORTANT AID IN BELL & SPIGOT JOINTING

***SPEEDS STERILIZATION*—First hypochlorite flushing provides sterile joint.**

Cross section

PROMOTES ECONOMY — FACILITATES REPAIRS EASILY APPLIED

ADVANTAGES IN DETAIL . . .

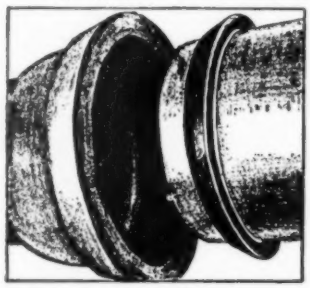
(1) PREVENTS CONTAMINATION — Rubber cannot harbor bacteria nor support their growth internally where water main sterilizing agents cannot reach them. The use of HYDE-RO Rings will prevent continued recontamination that has been traced in many cases to the joint packing.

(2) ECONOMICAL — The cost of HYDE-RO Rings is insignificant compared with the cost of repeated treatments with hypochlorite or the cost of sterilizing and keeping sterile (if it can be done), other types of packing.

(3) CONVENIENT — The installing of HYDE-RO Rings is a simple, easily understood operation. There is no measuring to be done and no cutting. The wrong size cannot be used. Since rings are solid, there are no laps to be inspected to see that they do not occupy too much of the joint space. The same ring fits pipe with bead on spigot or straight end pipe. The narrow iron blade used in caulking the ring automatically slips into the groove in the back.

(4) HOLDS BACK WATER — When HYDE-RO Rings are used, the pouring of wet joints is unnecessary. The rubber ring caulked tightly into place effectively dams off water from leaking valves and permits pouring of dry joints. This is especially important in repair work.

(5) CONVENIENT TO STORE — HYDE-RO Rings are supplied in cartons each containing fifty rings. The packages are light in weight and convenient to handle and store. Rings are manufactured for 4", 6", 8", 10" and 12" cast iron pipe.

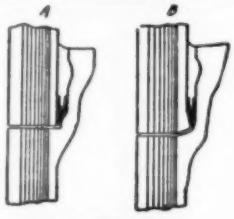


HOW RING IS USED

(1) Stretch the ring over spigot end of pipe with narrow end toward bell.

(2) Slide ring about 1½ inches from end of pipe; then slide the pipe home.

(3) Caulking the ring home, use narrow caulking tool about ⅛" or less in width.



Cross section showing the HYDE-RO Ring caulked into position on plain end (A) and beaded end (B).

HYDE-RO Rings can be used in conjunction with *Tegul*-MINERALEAD, lead or Portland Cement.

Tegul-AMPCO

For Bell & Spigot Terra Cotta and Concrete Sewer Pipe

Semi-rigid, sulphur bases makes tight, root-proof joints. Fills annular spaces completely to secure excellent joint. Reduces infiltration of ground water. Unaffected by dampness, frost or silt coating on pipe. Easily stored and handled. Immune to moisture and weather conditions. 5 lb. ingots; 50 lbs. to carton.

WATER WASTE SURVEYS AND LEAKAGE CORRECTION*

With Particular Reference to the Pitometer and Its Use in Making Such Surveys

By E. SHAW COLE

Vice-Pres. and Chief Engr., The Pitometer Co., Inc., New York, N. Y.

IT HAS been suggested that a pitometer survey be compared with a complete medical and physical examination such as would be made in a clinic. Various measurements would be made to determine the physical condition of the patient. The type of tests, the equipment and the technic have all been improved over the years, and, while these have probably resulted in better diagnosis, the basic tests have not been changed greatly. So it has been with the pitometer survey. Years ago the pitometer was called the x-ray of water works systems. Although new tools have been provided and technics improved to increase the efficiency of the survey, the basic flow measurements developed years ago are still important and valuable.

To carry the medical analogy one step further, let us consider that the counterpart of the general practitioner or family doctor is the water works superintendent or local engineer. While these men do splendid work and in some cases operate for years without any outside help or advice, it is quite common for a progressive doctor to send a patient to a clinic for a complete physical and medical examination. At the clinic are to be found doctors trained in this type of work—men who specialize in a particular field and for this reason excel in it. The need for an organization of engineers which specializes in conducting pitometer surveys and can be called on at any time to help in whatever way is desired, whether it be for a short test or a complete survey, is somewhat similar to the need for clinics. Perhaps this need is best illustrated by the fact that during the last five years, the author's firm has conducted a total of 251 surveys and tests in 159 different communities. The majority of these were water waste surveys that covered approximately 12,000 mi. of mains. This work resulted in the location and repair of over 6,500 hidden underground leaks wasting a total of 106 mgd. At an average purchase or production cost of five cents per 1,000 gal., this amount of water represents an annual saving of $1,935,000.

While the judgment of federal agencies is not necessarily the best criterion, it is interesting to note that the 251 surveys and tests included work for four large Navy shipyards, as well as for several cities where the FWA thought it sound practice to have a survey made before approving grants for expensive extensions and reinforcements. The federal government of one of our neighboring countries also authorized a pitometer survey in one of its cities, as the quickest and most economical means of obtaining an adequate supply for one of its largest arsenals. Also included are tests for important war plants, including a government arsenal, airplane manufacturing plants and oil refineries.

Scope of Pitometer Surveys

The pitometer survey is an engineering operation divided into two definite fields:

1. An accounting for all the water delivered to the distribution system, known as the water waste survey.
2. An engineering study of the existing distribution system to improve distribution facilities.

While the primary object of the pitometer water waste survey is to locate underground leakage, its scope is very much broader than this. The operations may be divided as follows:

1. Test of pumps for slip or efficiency.
2. Measurement of the flows at either end of gravity supply lines to determine leakage.
3. Measurement of the flow in and out of reservoirs to determine leakage.
4. Test of master meters for accuracy.
5. Measurement of the flow to various districts of the city. A study of the night rate of flow and its relation to the total, indicates the existence of leakage. Also, the information obtained is the basis for future design and extensions and replacements in a distribution system.
6. A test of large industrial meters and a check on industries for unauthorized use of water.
7. Night subdivision, or the analysis of the night rate of flow in districts where waste is indicated, which result in the measurement of the flow in every block or between every set of valves.
8. Location of underground leakage. By this method of night subdivision, every underground leak in the system large enough to justify the cost of repair is indicated by measurement and its exact location determined by the use of sound intensifiers.
9. House-to-house inspections, based on the result of night subdivision, are carried out for the purpose of controlling leaking plumbing fixtures in unmetered systems. In metered systems, the measurements provide indications of under-registration of domestic meters.
10. Special tests that include such things as river-crossing tests, industrial tests and measurements not mentioned above.

Not all surveys result in spectacular findings in each of these steps but the following examples are not unusual, and some of them have been encountered in otherwise well-operated systems.

Pump Tests

The logical starting point of any engineering project of this kind is the source of supply. In the early days where the supply was pumped, a test to determine the slip of the reciprocating pumps frequently showed amazing conditions. In some cases where maintenance was entirely absent, slip ran as high as 80 to 90 per cent, as could be demonstrated by shutting the discharge valves practically to the closed position without raising the discharge pressure.

As reciprocating pumps have been replaced by centrifugal pumps, the pump tests have come to include wire-to-water efficiency tests. These, too, sometimes show surprising conditions, as described in an excellent paper by H. E. Beckwith, entitled, "A Simple Method of Testing Centrifugal Pumps" (*Jour. A.W.W.A.*, 31: 2098 (1939)). According to Beckwith, it is not unusual to find a centrifugal pump which is operating under an entirely different set of conditions than that for which it was designed. He cites a test that gave a wire-to-water efficiency of only 40 per cent. The savings resulting from the installation of a pump designed to meet the operating conditions were very substantial.

Supply Lines

In gravity systems, the starting point for the survey is the reservoir and the gravity supply lines it feeds. A test of the gravity supply lines is made by measuring the flow at the inlet and at the outlet and, at the same time, leakage from the reservoir is determined by measuring the rise and fall in the reservoir, adjusted for the flow in or out, as the case may be. Where a long gravity supply line crosses rough and marshy country and possibly a river, it is important to know by direct measurement that there is no appreciable underground leakage.

The approximation of accuracy by any hydraulic instrument in the field is not much greater than 100 ± 2 per cent. In large gravity lines, a small loss could go undetected, due to the allowable error of the measurements. At the same time it should be pointed out that many losses have been detected where the difference between the inlet and outlet quantities did not exceed 3 to 4 per cent. In a survey for a small New Jersey system, a measurement of the flow in each end of a gravity line, 7 mi. long, showed discrepancies of 30 per cent between the reservoir and the town. The demands of this system had gradually increased over a period of years until it became necessary to install a booster pump in order to maintain an adequate supply. After the original discrepancy had been detected, intermediate gagings were made to localize the section where the loss occurred. Sound intensifiers were then used with positive assurance that leakage existed and a blown joint, which was wasting 250,000 gpd. into a large swamp, was quickly discovered.

Master Meter Tests

The testing of master meters for accuracy is a routine step that is necessary if figures on unaccounted-for water are to be used as the criterion for efficient operation and the absence of lost water. In the case where water is purchased through a master meter this test has a real dollar value and in two New Jersey communities substantial savings resulted from the discovery that the meters were over-registering. In one case there was an overcharge of 16 per cent. In the other instance, it was

*From the *Jour. AWWA*, 37, 181-188 (1945).

found that the flow through the master meters reversed during the night hours. Because the type of meter used registered positively, regardless of the direction of flow, this community was charged twice for water that was never used—once when it entered the system and again when it left it.

District Measurements

The division of a system into districts and the measurement of the flow into each district for a period of at least 24 hours provides information that is not only of value in indicating the existence of underground leakage, but gives valuable information regarding the operation of the entire distribution system. Primarily the district measurements are made so that the night rates of flow may be studied. The actual size of the district will vary but usually includes from 8 to 10 mi. of main and may be as large as 30 mi. A high flow at night of over 30 per cent of the total in the residential section of a metered system indicates the possibility of leakage and justifies further investigations, while a 40 per cent night rate is a sure indication of leakage or waste of some kind. A low ratio of night flow to the total flow, however, indicates that it would be uneconomical to make further investigations.

In cities where more than one survey has been made, a comparison with results of the previous district measurements provides a more exact means for predicting the existence of leakage. Some of our larger cities, notably Philadelphia, Pittsburgh, Rochester, Boston and Cincinnati, have found it economical to have a certain amount of work done each year, so as to keep their waste down to a minimum.

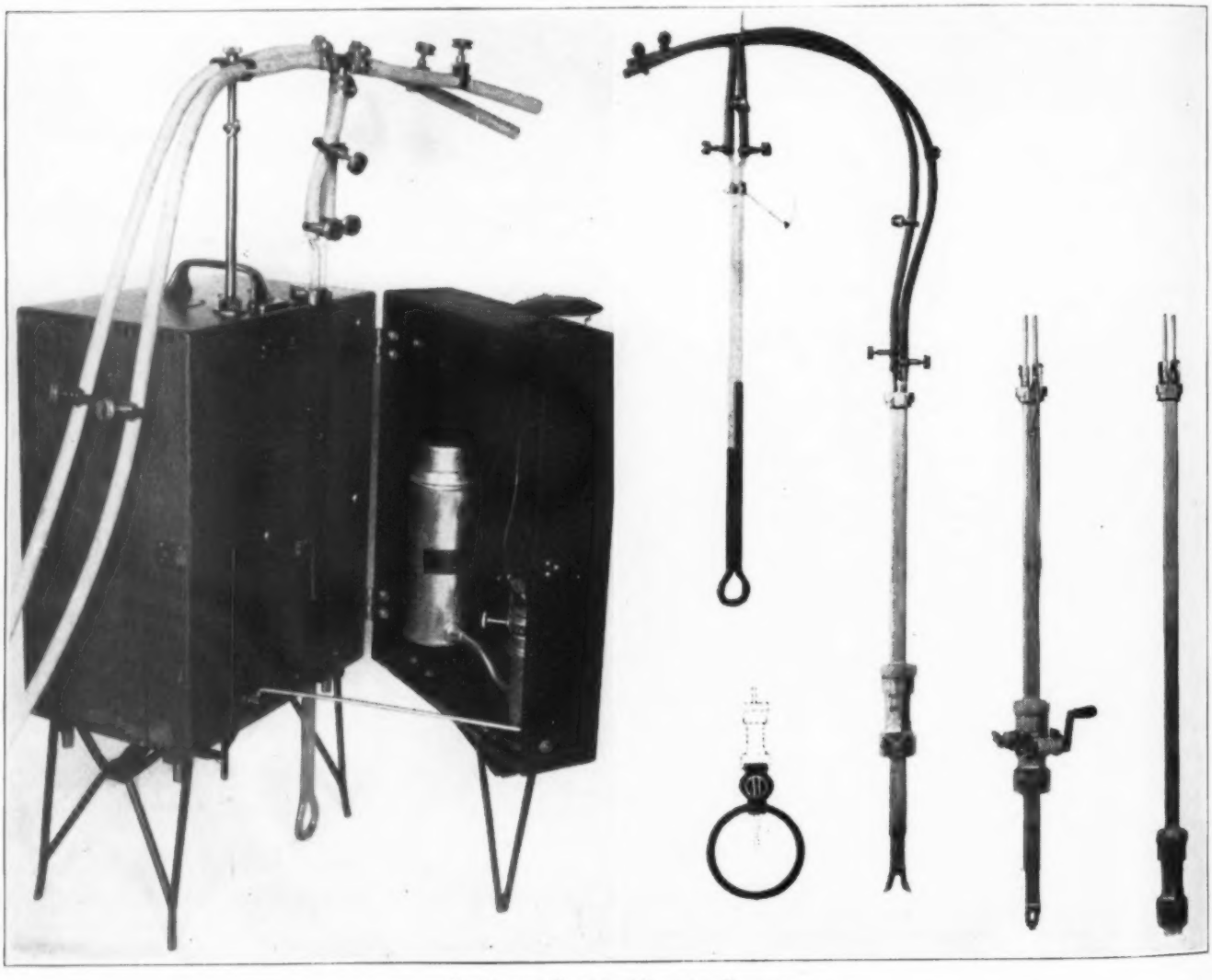
The district measurements are an important part of these annual surveys, for in this way it is possible to cover a large number of miles quickly by eliminating the many sections that are invariably found to be tight, and then to concentrate detailed investigations in areas that are definitely known to contain waste or leakage. In this connection it should be noted that the over-all accounted-for figures in large systems, where the consumption may be 30 to 40 mgd. or greater, are subject to so many variables with regard to consumption that it is not as easy to detect the presence of underground leakage as it is in a small compact system. A change of only a small percentage in a large system can involve more water than the entire consumption of the small system.

By isolating the districts by means of closed valves, so that the feed may be supplied through one or more large mains on which the pitometer is installed, it is possible to learn a good deal about the operation of the trunk mains. Pressures are taken before and after the district is isolated. The flows are studied and the adequacy of existing feeds taken into consideration, so that in case of fire there will be ample supply until the key boundary valves are opened in accordance with arrangements made between the fire and the water departments.

In one survey the formation of the district boundaries proved to be a difficult operation, due primarily to the condition of the valves and errors in the map. The time involved in solving the problem, however, proved to be well worth-while for the city because two of its important feeders were found to be carrying no water. Investigation showed that one 12-in. valve was closed, one double-check valve was frozen closed and one 12-in. valve was partly closed. The latter discovery explained the reason for inadequate pressures during a recent fire.

In another system there was a high area that had suffered from low pressures for years. When district measurements were being made at the start of a survey it was found that the principal feed, a 20-in. main, carried no water because of a 20-in. valve that was closed and too stiff to operate.

In addition to these not infrequent discoveries, district measurements always provide information regarding the consumption in the various sections of the system that are of value as a basis for designing extensions or reinforcements to the distribution system.



Equipment Used in Pitometer Survey

Photo Recorder — *Pitometer Rods and Monometer*

Industrial Meter Tests

Improved meter practice and close supervision of industria consumers has greatly reduced the loss of water in many systems, but there are still a large number of meter departments which do not make complete checks on the accuracy of the large meters and the use of water passing through them and through fire lines.

The advantages of testing large meters in place and under operating conditions, with the pitometer, may not be apparent to those meter superintendents who periodically use a test meter to check their meters. While it is true that there are some systems where the meters are in excellent condition, within three weeks two cases of under-registration involving large quantities of water were brought to light during routine field tests. In one large eastern city, a fire line meter was tested in spite of the fact that it showed no registration and that the factory said they were not using any water through it. The test showed that there not only was a flow but it was so large that a continuous test was run for a week. The average under-registration for this period was 427,000 gpd. and the rate varied from zero to maximum of 1,660,000 gpd. through a 6-in. pipe, or a velocity of over 13 fps. Four hundred and twenty-seven thousand gallons per day is not only a lot of lost water, but at a meter rate of ten cents per 1,000 gal. the lost revenue amounts to over $15,000 a year.

Night Subdivision and Leak Location

Following the 24-hour district measurement comes the problem of locating all underground leakage. Indirect gaugings are made to determine the distribution of the night rate of flow. These gaugings are made after midnight and before five o'clock in the morning. All mains, regardless of how small they may be, are included in these measurements and the unit of test is as small as it is practicable to make it with the valves available. Manifestly, if there is no flow into a piece of pipe after midnight there can be no leakage. Where an appreciable flow is shown to exist, further investigations are made to determine the cause. The importance of these measurements cannot be over-emphasized, because only in this way is there a *positive* indication of the existence of underground leakage.

The location of leaks has been a common occurrence in every water works since the first leak patrols were organized in England over 100 years ago and perhaps long before that. The main point to be emphasized here is the difference between the leak patrol or listening type of survey and the pitometer survey. By the periodic use of sound intensifiers leakage can be and is controlled by almost every water works plant. This type of control is excellent practice and should be encouraged. At the same time it should be recognized that this method is in a sense a negative control, *i.e.*, if no noise is heard on a main or its connections, it is concluded that there is no leakage; or if a slight noise is heard, and further investigation does not result in the discovery of a leak, it is concluded that the leak is too small to bother with, which may not be the case. Experience indicates that the intensity of sound does not necessarily indicate the volume or size of a leak.

An actual measurement of the flow between a set of valves when use is at a minimum, or is a known quantity, is a *positive* approach. Only after a water measurement is made can it positively be said that leakage does or does not exist, and, if there is leakage, only by a water measurement can the amount be determined. In the pitometer survey it is at this point that sound intensifiers are first used. Then with a definite knowledge of the size and approximate location of the loss, investigations are made with whatever type intensifier the engineer prefers, until all leakage of sufficient importance to warrant repair is located.

The record is full of instances where the sound indications were so misleading or faint that large leaks had existed for years. Take, for example, interfering noises from pumps, motors, regulating valves, machinery, etc., or the case of a deep fill, a river-crossing or an abandoned service.

In this connection it is worth noting that the quantity of leakage located, rather than the number of leaks, is the important consideration to a community. For example, a survey was made in a metered New England city having a domestic per capita consumption to 64 gpd. Only a handful of small service leaks were found in the distribution system proper, but because the survey was a complete audit, a measurement was made on a pumping line leading to a reservoir some distance out of the city. This main crossed some rough and swampy ground and there were no connections to it. The function of the pump station was to augment the main gravity supply to the reservoir and whenever the water level dropped to a certain point the pump started and ran until the reservoir was filled. The measurement on this main showed a loss between the pump station and reservoir of 430,000 gpd. and further investigation resulted in the discovery of a leak wasting 250,000 gpd. into the swamp, when the pump was off, and 390,000 gpd. when it was operating and the pressure thus increased. This one leak was largely responsible for the need of pumping, as it was continuously draining the reservoir. The savings in pumping costs alone amounted to $4.50 per day at one cent per kilowatt hour.

At the other extreme, is the case of a large unmetered gravity system where leakage and waste were rampant because there was an abundant supply. Unfortunately, the capacity of the 7-mi. transmission mains was limited and shortly before the war the demand had increased to the point where pressure troubles developed and it was necessary to curtail service in order to get water into the large distribution reservoir. Then with the war came a large arsenal that demanded 10 per cent of the total consumption. This additional amount could not be supplied and so the government authorized a complete pitometer survey as the quickest and most economical approach to obtaining an additional supply. Here the resultant action could be called selective leak location. Only the large leaks were dug up and repaired at first so as to reduce consumption as rapidly as possible, and in this case measurements were invaluable. Hydrant leaks making a terrific roar were encountered on almost every other corner, and yet broken mains, part of the time submerged by the tidal river, made no noise at all on the surface of the street due to the nature of the ground conditions and undermined pavements. Within six weeks, leaks releasing over 4 mgd. had been repaired and at the completion of the survey leaks totaling 13 mgd. had been located.

Other Benefits of Subdivision Studies

In addition to providing positive information regarding leakage, the night subdivision measurements have several other valuable features. During the course of the measurements, it is necessary to close a large majority of the valves in the distribution system and prove their condition by making tight shut-outs. Periodic inspections and operation of all valves in a distribution system is generally considered good practice. Usually, however, shut-outs are not made during the inspection, the main object being to see that the valve is free and in good condition. When a survey is made the night valve operations can take the place of the annual inspections. Many systems do not follow a valve maintenance program at all and in these cases the operations made during the survey are useful, not only as a check on the condition of the valves, but also on the distribution system map and records. One of the most interesting discoveries resulting from valve operations occurred in a southern city where it was found that a great many of the mains were not connected at intersections. This, it was said, came about as a result of street grading after part of the system had been installed, thus increasing the cover. When the gridiron was completed, no effort was made to connect mains that were at different depths. Only by methodically proving how the water was circulating were all these missing connections located, and the improvements in the strength of the distribution system after connections were made can be readily appreciated.

House Waste

The only sure way to eliminate unnecessary waste on the consumer's property is by universal metering. There are, however, many communities where universal metering is impractical for financial or political reasons, and in these communities only the largest consumers are metered.

The only other method of controlling this waste is by periodic house-to-house inspections and these are most efficiently supervised when the amount of water being wasted is first determined by night measurements. Following these, concentrated work in those sections found to have a large night consumption will produce the best results.

The benefits from these inspections are only temporary unless repeated at regular intervals and even then have no control over willful waste. However, a pitometer survey will indicate the most wasteful sections and several cities have adopted ordinances authorizing the water department to install meters when re-inspections show that the consumer is a chronic waster of water and will not keep his fixtures in repair.

Distribution Studies

A second type of survey, the distribution study, has an objective somewhat different from the waste survey. Basic data accumulated through loss-of-head tests, fire flow tests, pressure and hydraulic grade line studies and computations are all dependent on a variety of flow measurements and gagings. The pitometer distribution survey is of value in determining the true physical condition of a distribution system before designing improvements.

Whether the problem be the location of points of waste or the proper method of extending or improving the distribution system, the pitometer survey will be found to be a most valuable method of finding the proper solution.

PROGRAM FOR ROUTINE TESTING AND MAINTENANCE OF METERS*

By G. L. WILLIAMS

Analyst-Statistician, California Water Service Co., San Jose, Calif.

SOME kind of a program for the maintenance of water meters is dictated by good business management, which always requires careful consideration of each item of expenditure in the light of its contribution to the business as a whole. In the water business, which is caught between fixed rates for what it sells and rising costs of operation, and which faces unprecedented demands for service at a time when the construction dollar buys less and less, the necessity for such practical considerations is brought home very forcefully.

In initiating a program for the routine inspection and maintenance of water meters, the practical extent of the program and the proper interval for periodic maintenance must first be determined. The steps taken by the California Water Service Co. in developing such a program may be outlined herein, with the intent to obtain the answers to these questions and, at the same time, co-ordinate the routines necessary for the successful operation of the program and provide means for supervisory review of its effectiveness.

Planning the Program

As a first step, it was considered necessary to know the number of meters involved and their types and sizes, as well as the number of years they had been in service since the last test. Accordingly, these data were accumulated and then tabulated according to meter size and type and number of years in service. In considering the results, it was decided that certain sizes and types of meters, of special characteristics and limited number, would be treated as special cases, subject to replacement as opportunity afforded or to special consideration not covered by the general program.

With this information available, it was possible to:

1. Make an analysis of the costs of reconditioning.
2. Determine the average change in registration and consequent loss of revenue with years in service.
3. Determine the proper periodic interval for inspection, test and repair.
4. Develop methods for following up the results of the program.
5. Prepare a service manual by means of which all members of the organization could become fully acquainted with approved methods and practices for inspection, test and repair, as well as with the routines necessary for effective compliance with the program.

Cost of Reconditioning

Although the average cost of meter reconditioning was available from existing records, it was decided that the figures would be of little value, first, because they lumped together costs for all types and sizes of meters and were based on some questionable practices, and second, because such costs could not be used to establish standards of what constituted an efficient job.

A thorough review of the current methods and practices of testing and repairing meters was made, and provision was made for such changes as were considered necessary. After incorporation of these changes, a study was made of the cost of the material and the time required for each operation. From this study there was obtained an analysis of the cost of reconditioning, as shown in Table I, detailing both the costs applicable to all meters (including removal, transportation and resetting) and the costs dependent upon the physical condition of each meter (such as the expenses involved in replacing pistons, measuring chambers and other parts). By applying these costs to the operations performed on meters of varying service ages, it became possible to compute the cost of reconditioning according to the length of time in service as well as by types and sizes.

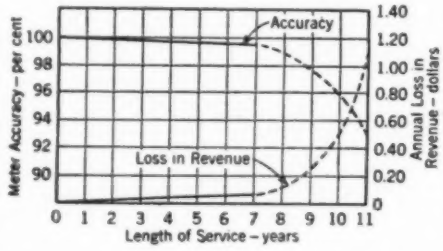


Fig. 1. Decline in Meter Accuracy and Revenues

TABLE I

Costs of Removing, Testing, Repairing and Resetting ⅝-in. Meters*

Operation	Itemized Cost	Cost For 100 Meters
Removing and resetting		$ 45.00
Average transportation cost		6.00
Test before repair (labor)		6.30
Disassemble, examine, clean, reassemble		
Material	$ 9.70	
Labor	47.50	
		57.20
Test after repair		
Labor—9 minutes each		
Less—3 minutes each (on other work)		
Net—6 minutes each		9.50
Total cost applicable to all meters		$124.00
Replace piston		
Material	$ 84.00	
Labor	7.00	
		$ 91.00
Replace intermediate gear train		
Material	$185.50	
Labor	7.00	
		192.50
Replace measuring chamber		
Material	294.00	
Labor	7.00	
		301.00
Replace register (R.R.)†		
Material	122.50	
Labor	6.00	
		128.50
Replace register (S.R.)†		
Material	175.00	
Labor	6.00	
		181.00
Replace balls		
Material	21.00	
Labor	7.00	
		28.00
Miscellaneous		
Material	45.00	
Labor	9.00	
		54.00

* Figures are illustrative only.
† R.R.—round-reading; S.R.—straight reading.

Accuracy in Service

Where past records of tests are available, changes in the accuracy of registration with years in service can be ascertained:

1. By an analysis of the results of the tests of meters which had been removed from service for reasons other than nonregistration, weighted against the average consumption at the rates of flow used for the tests.
2. By placing meters which have passed the required tests in series with meters of representative customers.

Although many more meters can be used as a basis for the study by employing the first method than is practicable with the second, the former encounters the problem of converting differences in accuracy at test rates to a weighted average consumption at these rates. Practically, therefore, the same limitations are imposed as under the series test method. For this reason, as well as the fact that information available under past testing procedures was limited, the series test method was chosen as being more direct and probably more conclusive under existing conditions.

For the tests, 30 test meters were placed in series with the service meters of representative customers in districts which were chosen either because a cross-section of a large number of metered customers could be obtained or because special service conditions were encountered. In selecting representative customers, care was taken to include those which would give a fair sampling of the district's use of water. Also, because there was no evidence that changes in accuracy of registration would be evenly progressive with years in service, test meters were divided among those customers whose meters had been in service for 4, 7 and 11 years.

Readings of both test and service meters were taken at the time of installation and again after 30- and 60-day intervals. These data were arranged as shown in Table 2 in order to show differences in registration and in percentage of accuracy in comparison with the test meters for the three service years selected. The results are shown in graphic form in Fig. 1. It is notable that the average of all service meter registrations remains substantially in line with the test meters up to 7 years in service, after which there are enough meters with considerable under-registration to pull down the overall average quite rapidly. Although the results were different in detail in each of the several districts from which data were collected, the characteristics of the curve were the same in all districts.

To forestall any questioning of the "100 per cent accuracy" assumed in the foregoing examples, it should be explained that, as all computations were made against the average accuracy of meters which had been calibrated within allowable percentages at each rate of flow, 100 per cent accuracy is assumed to be that of the average meter as placed in service. Also, it should be borne in mind that Fig. 1 indicates the average condition of service meters at given years of service; any individual meter may vary rather widely from this average.

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Economic Maintenance Period

The time to recondition meters is when the cost of reconditioning is less than the cost of leaving the meter in service; in other words, when the annual cost of reconditioning is less than the annual loss of revenue. Reference to Fig. 1 shows that there is very little loss of registration accuracy for the first 7 years of service. After reconditioning, therefore, it can be expected that the average meter will follow the original performance curve, which, for these particular meters, means that their accuracy will be approximately equal to that of test meters up to 7 years of service, after which the same rapid decline in accuracy of registration will occur.

Conversion of registration losses into terms of losses in revenue is simple if only one rate applies. For the test, the number of step rates for varying consumption blocks and the practice of allowing a given volume of water for the minimum charge made it necessary to make an analysis of customer useage in order to determine the loss. A cross-sectional sampling of customer usage was made to determine the average number of customer months of consumption in each rate block, as well as the number of months under the minimum. This made it possible to determine the average loss in revenues for each drop of 1 per cent in meter registration. In Fig. 1, therefore, loss in revenues corresponding to loss in registration has been plotted against years in service.

By comparing the annual loss in revenue with the annual cost of reconditioning as previously obtained, the results might be:

Years of Service	Annual Loss In Revenue	Annual Cost of Reconditioning
7	$0.06	$0.33
8	0.32	0.33
9	0.90	0.29
10	1.56	0.26
11	2.65	0.24

These results show that meters should be reconditioned after nine years in service. In computing losses in registration, however, only two points were available, one at the 7-year and the other at the 11-year mark; and, because of special conditions, the computation assumes a straight line between these points, although a more usual performance would follow the curve shown in Fig. 1. As a further check, five test meters were shifted to other customers whose meters had been in service for the number of years indicated as the economic interval for reconditioning, readings being obtained after a 30-day interval. This is a further refinement that may or may not be justified in all cases. In any event, under the conditions shown, the conclusions reached will not, for practical purposes, be greatly changed. The important conclusion reached from the study was that the period for reconditioning lies somewhere between 7 and 11 years of service.

TABLE II

Comparison of Service and Test Meter Registration*

Acct. No.	Meter No.	Service Meter Reading		Water Registration by Service Meter	Test Meter Reading		Water Registration by Test Meter	Accuracy of Service Meter
		Start of Test	End of Test		Start of Test	End of Test		
		gal.	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*	*per cent*
501	2042764	290	4,500	4,210	0	4,120	4,120	102
2816	2042771	76,040	81,790	5,750	90	7,740	7,650	75
919	2164599	50,060	55,260	5,200	0	5,350	5,350	97
3011	2164502	3,780	11,400	7,626	0	7,740	7,740	98
10922	2164148	15,070	21,870	6,800	0	6,750	6,750	101
15216	2423079	95,710	97,920	2,210	150	2,470	2,320	95
7900	2563997	86,570	93,220	6,650	0	7,590	7,590	88
11218	3646093	15,980	16,720	740	0	770	770	96
8615	5163846	18,350	20,410	2,060	0	2,010	2,010	102
14066	5251463	57,230	58,430	1,200	0	1,290	1,290	93
TOTALS				42,440			45,590	93

* Meters in service 11 years, in Stockton Dist.

Schedules and Reports

After establishment of the maintenance period, the information concerning the number of meters in service was utilized to lay out a schedule of the number of meters which should be removed from service for reconditioning over a given period. In order not to establish peaks in maintenance which would be beyond the capacity of facilities and personnel, this schedule was arranged to give as near an even annual load as was practicable, beginning with the older meters.

In actual practice, reference is made to a "meter history card," which shows the date of the last test, and an order for removal is sent to the field. The meter is removed from service, tagged with its identification and the reason for the test, and sent to the meter shop. Records of tests before and after repair, as well as code classifications indicating the reasons for and the extent of repairs, are made out in the meter shop for each meter received for routine test as well as for those received for other reasons. One copy of this test data sheet is used to record the pertinent data on the "meter history card"; the other copy is used to tabulate the number of meters reconditioned, showing cause of reconditioning and class of repair. Comparisons are made periodically of the number of meters reconditioned and the number scheduled for the period.

A standard or normal cost of reconditioning is obtained for each meter shop by applying the unit cost of reconditioning (obtained previously for purposes of the study) to the meters reported on the test sheets. The actual costs of reconditioning (as shown by the books) is compared periodically with this cost in order to detect any discrepancies which warrant further investigation and correction.

Meter Service Manual

A very important product of the program was the preparation of the *Water Meter Service Manual*. A complete description of this manual, which covers all phases of meter installation, replacement, testing and repair, as well as general useful descriptive data and illustrations, is beyond the scope of this paper. Its general usefulness may best be shown by pointing out that the very act of setting down practices and procedures in complete detail served to bring out very forcibly those weaknesses which had crept in unnoticed.

General Application

Although the detailed methods used and the results obtained will be dictated largely by local service conditions, it is believed that the over-all approach to the problem described above is generally applicable. In these tests, 21 separate operating districts were involved, for which 5 meter test and repair shops are provided. The considerable number of operating districts, with their varying service conditions, tended to make the preliminary analytical work and checking procedures somewhat more elaborate than probably would be justified in all communities. As a result, however, it became possible to obtain otherwise unavailable comparative data.

HOW MUCH LEAKS COST YOU

SIZE OF OPENING	AIR 100 Lbs. Pressure		GASOLINE 15 Lbs. Pressure		WATER 40 Lbs. Pressure	
	Cu. Ft. Wasted Per Month	Cost at 10c Per M	Gal. Wasted Per Month	Cost at 4c Per Gal.	Gal. Wasted Per Month	Cost at 15½c Per M
3/8"	9,979,200	$997.92	423,000	$16,920.00	692,400	$108.00
1/4"	4,449,600	444.96	188,000	7,520.00	307,700	48.00
1/8"	1,114,560	111.46	47,100	1,884.00	76,900	12.00
1/16"	278,640	27.86	11,800	472.00	19,200	3.00

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Est. 1854

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The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

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Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

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CLEANING, PAINTING, AND PROTECTING STEEL WATER TANKS

By JOHN M. PERRYMAN
Engineer, R. D. Cole Mfg. Co., Newnan, Ga.

STEEL water tanks and towers should receive careful annual inspections and not suffer from neglect. Some estimates of cost, intended to provide ideas of the amounts involved to properly protect water tanks of various sizes, are given in this article.

Leading designers, fabricators and erectors of steel water tanks are in position to offer inspection service and competent advice as to necessary work that may be required to maintain or place tanks in the best of condition. This service will usually cost from $100.00 to $150.00, depending upon the location.

Paint has been and still is the proven method for the protection of steel, although, through research and experience, other methods are being used. Therefore some are mentioned for your consideration.

Even the best paints will not adhere to rusty steel without the steel having been properly cleaned of all loose rust, grease and old loose paint. Thorough wire brushing is all that is really necessary, although in badly corroded structures more severe methods may be required, such as sand-blasting. See specifications at end of this article.

The ideal time to clean, paint and repair is during the late spring and the early fall months, and never when temperatures are likely to be less than 50 degrees, and the ideal is from 60 to 70 degrees.

Good Paint Is Good Economy

The use of good paint is good economy. Since labor is the governing factor in the cost of painting, amounting to approximately 80 per cent of the total cost, the use of the better grades of paint adds little to the final cost.

The American Water Works Association and some insurance underwriters have published specifications for proper methods of tank cleaning and paints that are satisfactory. Therefore it is suggested that you communicate with them or with the manufacturer of your elevated tank, in order that you may secure the best available information before proceeding with the cleaning and painting of your water tanks.

A fact to remember is to "repair" before painting, so it is desirable that you secure the advice of experts before proceeding with your painting. When experts are mentioned, do not be misled by false or misleading statements. Remember the loads involved in water tanks of the elevated type are highly concentrated—and the advice of so-called "steeple-jacks" that are not professional engineers cannot, therefore, be relied upon, as usually they do not have knowledge of the stresses or the methods of calculating stresses to advise you fully as to the strength or weakness in a steel tank. It is suggested, therefore, that you ask for credentials or other evidence as to one's ability to pass judgment on tank details, as this is highly important.

CHART NO. 1

Gallons of Paint Required Based on 100-ft. Towers

	50,000 Gals.	75,000 Gals.	100,000 Gals.	150,000 Gals.	250,000 Gals.	500,000 Gals.
First Coat Inside....	8	10	12	15	25	50
First Coat Outside...	12	14	17	22	35	70
Second Coat Outside.	12	14	17	22	35	70
*Riser, per coat.....	3	3	3	3	3	3

Note: The 3 gallon requirement is for 3′ diameter risers. For 4′ diameter riser, add 3 gallons; for 5′ riser, add 6 gallons per coat.

Furthermore, before entering into a contract be certain that all work to be done has been agreed upon in writing, and that no hidden clauses are in the contract which entitles the person or persons doing the repair work to proceed with additional repairs or replacements without written advice and predetermination of cost.

Estimating Paint Requirements

Now let us consider quantity of paint involved to properly paint your tank. Chart No. 1 gives the average quantity of paint required, and I believe that this is fully self-explanatory. This chart is for your guidance and should take care of all popular sizes of elevated steel water tanks.

Paints of the highest quality can currently be procured at about the following prices:

Red lead—$4.50 per gallon.
Black interior water tank paints—$3.50 per gallon.
Aluminum and other high grade exterior paints for steel structures at approximately $4.00 per gallon.

Sample Estimate

You may refer to Chart No. 1 and secure therefrom the amount of paint required for your tank, and then total the approximate cost as illustrated:

Take, for example, 100,000-gallon elevated tank together with a steel tower 100 feet high and a 3-foot diameter steel riser and calculate as follows:

1—Inside red lead (15 gals.) @ $4.50	$ 67.50
2—Inside black paint (15 gals.) @ $3.50	52.50
1—Outside red lead (5 gals.) @ $4.40	22.50
1—Outside aluminum (40 gals.) @ $4.00	160.00
Total for materials	$ 302.50
Add for labor and incidental cost, four times the cost of paint	1210.00
Total cost for doing a nominal amount of wire brushing, both inside and outside, replacing manhole gaskets, and stopping any small leaks (not to exceed 10), total cost	$1512.50

When Using Cathodic Protection

In lieu of painting the tank complete on the inside you may calculate the approximate cost of painting the underside of the roof and top ring on the inside of the tank and the outside of the tank to be painted with two coats of paint and for the inside using cathodic protection. The cost will be about as follows:

Inside red lead (5 gals.) @ $4.50	$ 22.50
Inside black paint (5 gals.) @ $3.50	17.50
Four times materials for labor	160.00
Scaffold	50.00
Cathodic unit installed (see Chart No. 2)	600.00
Total	$850.00

And to the above you must add the cost of the outside painting (see first tabulation, items 3 and 4):

Paints for outside	$ 182.50
Four times material for labor	730.00
Total cost of painting the outside	$ 912.50
Cost of painting outside of tank and tower, painting underside of roof and installing Cathodic Protection on inside	850.00
Total cost	$1762.50

Bituminous Enamel Interior Coating

Another method of protecting the inside is with the use of one coat of bitumastic priming solution and one coat of bitumastic enamel on the inside of the riser, the bottom and shell of the tank and painting the underside of the roof two coats of bitumastic solution. The approximate cost of doing this work is about $1350.00 for applying bitumastic enamel on the inside and the cost of painting the outside of the tank, $912.50, giving a total of $2262.50.

From the above illustrations and using charts No. 1 and No. 2 you can approximate the cost of cleaning and painting your tank, applying cathodic protection to the inside or using the bitumastic enamel.

In using the above estimates, remember excessive cleaning, repairs and replacements *are not included* in the estimates of cost outlined, nor does the information given outline the advantages or peculiarities of any of the principal methods of giving protection to your tank; nor do they include estimates of life expectancy or protection, upkeep of operating devices and operating cost of the electrical protective devices.

CHART NO. 2

Cathodic Protective Units

The approximate cost of Cathodic Protection, not including cost of cleaning the inside of tank, nor painting the underside of the roof and top shell ring:

50,000 gallon tank	$500.00
100,000 gallon tank	600.00
250,000 gallon tank	800.00
500,000 gallon tank	1000.00

Cost of painting underside of roof and top shell ring:

50,000 gallon tank	$225.00
100,000 gallon tank	250.00
250,000 gallon tank	400.00
500,000 gallon tank	600.00

Approximate cost applying one coat Bitumastic Solution and one coat Bitumastic Enamel to riser, bottom and shell and two coats Bitumastic Solution underside of roof:

50,000 gallon tank—3′ riser	$1200.00
100,000 gallon tank—3′ riser	1350.00
250,000 gallon tank—4′ riser	2300.00
500,000 gallon tank—5′ riser	3500.00

PITTSBURGH-DES MOINES STEEL CO.

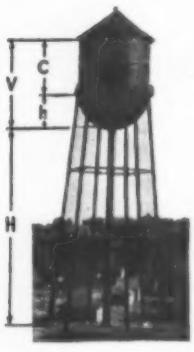
Tanks—Plate Fabrication—Structural Steel

Plants at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE ST., DES MOINES, IA. . . . 625 ALVISO RD., SANTA CLARA, CAL.

Other Sales Offices at: ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL. . . . 1223 PRAETORIAN BLDG., DALLAS, TEX. 926 Lane St., Seattle, Wash.

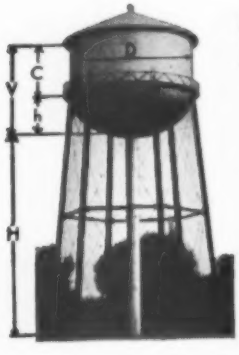
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



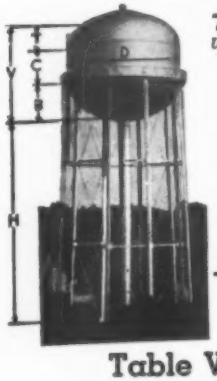
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	88 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
400,000	40	30 0	46 6	44 6	52 10	61 2	76 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	35 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



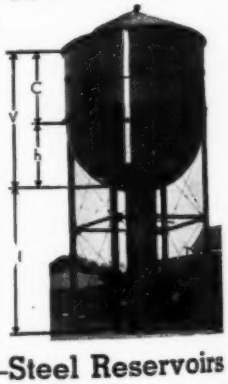
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 8	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 8
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks



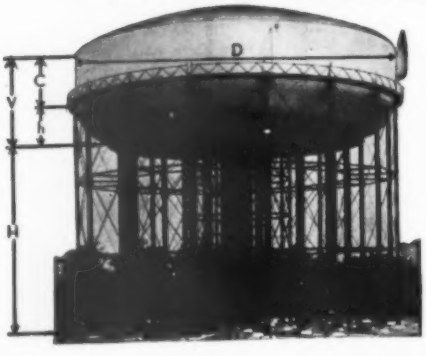
Capacity in U.S. Gallon	D	B	C	T	V	H
50,000	24'-0"	9'-10"	9'-4"	4'-4"	19'-6"	Built to Order
75,000	26'-0"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	24'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	16'-0"	9'-0"	12'-11"	6'-9"	28'-8"	
250,000	10'-0"	10' 4"	11'-7"	7'-6"	29'-5"	
275,000	40'-0"	11'-11"	13'-9"	7'-6"	33'-2"	
300,000	40'-0"	8'-7"	17'-11"	7'-6"	34'-0"	
350,000	44'-0"	14'-8"	13'-10"	8'-0"	36'-6"	
400,000	46'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	40'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000	45'-0"	14'-4"	14'-0"	10'-0"	38'-4"	
750,000	50'-0"	15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	11'-8"	15'-9"	11'-0"	48'-5"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
25,000	15	14	7	19	11	
30,000	17	12	7	19	0	
40,000	19	13	1	20	6	
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks



Capacity in U.S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0" ft.	in.	V = 25' 0" ft.	in.	V = 30' 0" ft.	in.	V = 35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	Built to Order
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	
1,500,000	115	2	102	9	93	9	86	8	
2,000,000	132	8	118	5	108	0	99	11	
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	in.
50,000	20	21	6
60,000	22	21	6
75,000	24	22	4
100,000	26	25	3
150,000	30	28	3
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	6
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	3

OPERATION OF PNEUMATIC STORAGE TANKS

by J. B. WILKINSON, M.E.
Chief Engineer
Fire Ins. Rating Bureau, Milwaukee, Wis.

A PNEUMATIC storage tank as used in municipal water works serves the twofold purpose of maintaining domestic pressures within a selected range and of supplying a continuous domestic demand with intermittent operation of a pump.

Low initial cost is amongst the reasons for selecting this type of storage instead of an elevated tank or reservoir. However, pneumatic storage is the most expensive type of water storage in terms of cost per gallon of storage. This is the case because, as will be shown later, the useful capacity within the desired pressure range is usually only a small fraction of the full volume of the tank, and also because the tank must be heavily constructed to withstand the maximum system pressure. It follows that pneumatic storage rarely is large enough to make an important contribution to fire protection, and the usual location is at or near the pumping station. On the other hand pneumatic storage may frequently be justified for betterment to water service on the fringes of water supply systems serving residential areas.

Typical main installations are found in small villages of a few hundred population. The horizontally-mounted tank is cylindrical in cross-section, has dished heads and access manhole, and fabrication conforming to the ASME code for unfired pressure vessels is indicated by stamped marking on the shell. Diameter may be 8 or 9 ft., and gross capacity 16,000 to 20,000 gallons. Larger or smaller tanks are used according to the size of the system. Connection is made from the bottom to a distribution main (a 4 in. pipe for such connection is ordinarily sufficient) and from the top to the compressor used to replenish the cushion air from time to time. The air line should have a renewable-disc angle globe valve at the tank, and toward the compressor a bronze-seat check valve and a brass pop relief valve of the same size as the pipe. The latter should be set to blow at 10 per cent above the maximum operating or design pressure of the tank, whichever is the smaller. A gage glass reveals the air-water level. Automatic operation of a pump is provided for by a pressure-actuated starter, or a float switch can be used.

Two or more tanks can be operated as a unit by connecting discharge and air lines to common headers. Such installations are not usual because one larger tank will provide equal storage at less cost.

Operating Considerations

Operators of pneumatic storage systems may be uncertain as to where the air-water level should be carried for best results. Operating conditions vary widely and there is no single answer which applies to every case. The objective is to secure the largest possible effective storage with the smallest possible variation from the average pressure wanted in the system. But relatively large volume is associated with a wide pressure range; conversely, close pressure regulation is obtainable only by lessening effective storage.

There is some minimum pressure that must be maintained to provide the desired service. This may be 40 lb. in a place where domestic supply is the principal consideration, or may be 60 lb. or more where buildings are high, topography irregular, or sufficient pressure for fire streams is wanted for the short time required to get an operator to a normally unattended pumping station.

Having decided upon the minimum required pressure, the next step is either to select the range of operating pressure, or to determine the storage neded to supply the demand without too frequent starting of the pump. The top pressure will be the governing consideration in some instances —as where certain areas are low and pressures correspondingly high. Or, when the demand is relatively large and approaches the capacity of the pump, the largest possible storage may be wanted to lengthen the operating cycle. But in any given installation, fixing either of these factors automatically affects the other.

Calculation of Pressure-Volume Relations

Air trapped above the water in a pneumatic storage tank is an elastic medium. Pressure-volume relations follow Boyle's law which, briefly stated, is that at constant temperature—approximately true in actual practice—the volume of the confined air multiplied by its absolute pressure gives a number which is always the same for the particular container holding the same amount (weight) of air.

This relation, expressed mathematically, is represented by the formula

$$PV = C,$$

where P is the *absolute** pressure in lb.
V is the *air volume* in any convenient unit, such as cubic feet or gallons.
C is a *constant*—that is, the fixed number referred to in the preceding paragraph.

To illustrate the application of this formula to a pneumatic equalizer, assume an 18,000-gallon tank containing 9000 gallons of air over water; the pressure gage shows 45 lb. The volume of the air is wanted when water is pumped in until the pressure is raised to 60 lb. gage. It will be convenient and sufficiently accurate to assume that atmospheric pressure (which must be added to the gage reading to give absolute pressure) is 15 lb.

$$C \text{ (is the constant)} = P \times V = (45 + 15) \times 9{,}000 = 540{,}000$$

Having determined this constant, the air volume at 60 lb. gage becomes

$$V = \frac{C}{P} = \frac{540{,}000}{(60 + 15)} = 7{,}200 \text{ gallons}$$

and the water stored is the tank capacity minus the air volume, or 10,800 gallons.

Chart of Pressure-Storage Relations

Numerical calculations of the sort shown are cumbersome, and several must be made to cover the entire operating range. The accompanying Pressure-Storage Relations Chart has been prepared to make such calculations unnecessary, and at the same time express the relations directly in terms of water volume and gage pressure.

The numbers on the lower horizontal axis are pressures as shown by the gage on the tank. Those on the left margin refer to the volume of water in the tank, expressed as a percentage of the total tank capacity.

If the operating condition at any time is indicated by a point on the chart at the intersection of a water-stored and a pressure line, corresponding pressure-storage relations when water is pumped in or withdrawn will lie along a diagonal line drawn through this point parallel to the several diagonals on the chart. These last are marked 0, 10, etc., the numbers indicating the residual pressure which will remain when the tank has been emptied without escape of air.

Uses of the Chart

Example I. Assume a 20,000-gallon tank to be half full at mean operating pressure of 50 p.s.i. gage pressure. This condition is represented by a point at the intersection of the 50 per cent storage and 50 lb. pressure lines. Through this point draw a parallel diagonal; it will be about midway between the 15 and 20 lb. diagonal lines. As water is pumped in or withdrawn, the pressure-storage relations will be along this line. Thus, if water is pumped in until the pressure is 60 p.s.i. gage, storage will be 57 per cent of the tank capacity, and if water is withdrawn until pressure falls to 40 lbs., storage will be only 41 per cent of full capacity. It follows that effective storage within the pressure range of 40 to 60 p.s.i. is the difference. In this instance it is 16 per cent (57-41) of 20,000 = 3200 gallons in the operating range of 20 lbs. around a mean of 50 lb.

Example II. Assume the tank and pressure range to be the same as in Example I, but that the operator wishes not to risk delivery of air to mains in case of power outage or failure of automatic pump controls. The diagonal line marked "O" applies to this condition. At 40 and 60 lbs. pressure, the tank will be filled to 72½ per cent and 80 per cent of full capacity at the respective pressures, and effective storage within this pressure range will be only 7½ per cent (80-72½) of 20,000 = 1500 gallons. Note that the low terminal pressure has been secured only by very substantial reduction in effective storage; this may not be objectionable if it does not cause too frequent operation of the pump. Or retaining the zero terminal pressure, more storage can be had by broadening the pressure setting.

Example III. Again considering the same tank and operating range of 20 lb. around a mean of 50 lb., maximum effective storage will be had when the tank is empty at the lower pressure setting. To provide a small margin of safety against delivery of air in normal operation, let us assume that the tank is conditioned for terminal pressure of 35 lb. (5 lb. below the pump starting pressure). On the diagonal for 35 lb. taken as the zero storage axis, storage of 9 per cent and 33 per cent will be found at 40 and 60 lb. pres-

*Absolute pressure is gage plus atmospheric pressure.

sure respectively. Effective storage is the difference (33-9), or 24 per cent of 20,000 = 4800 gallons. However, lacking an accessory device that would release the remaining air at a predetermined low water level in case the pump should fail to start, a conservative operator would probably prefer a condition more like that outlined in Example I or II wherein a lower storage valve is maintained.

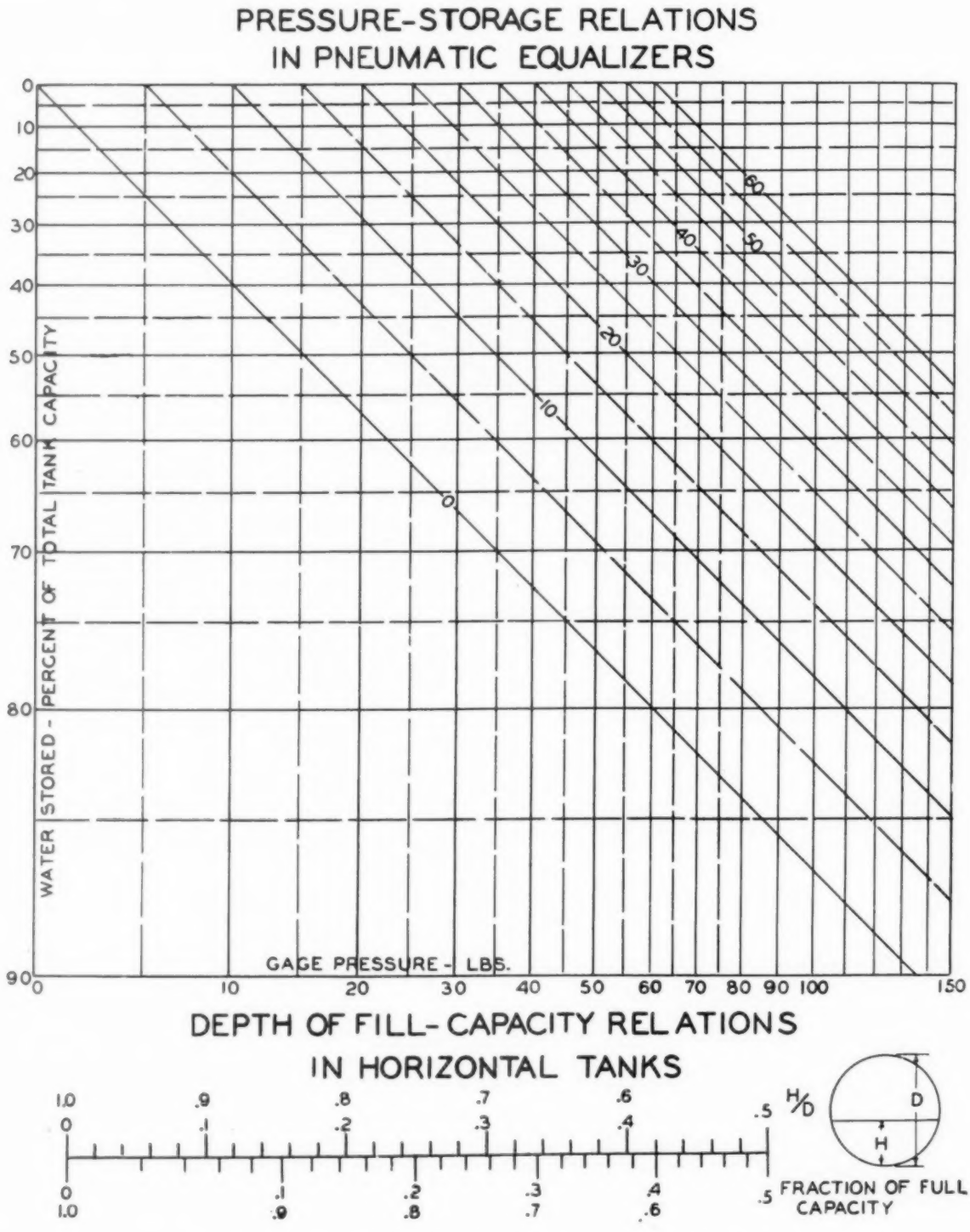
Water Depth-Volume Relationship

There remains the problem of relating water volume to the level carried in the tank. The Depth of Fill-Capacity scale at the bottom of the chart is for this purpose. It does not take account of the capacity in dished heads, but the error will be negligible for practical purposes.

This scale has dual markings, the inner numerals (those nearest the scale) applying to tanks less than half full, the outer figures to those more than half full.

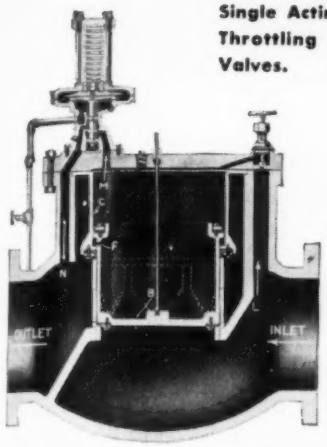
The H/D scale above the central line indicates the extent to which the tank is filled as a decimal fraction or per cent of its diameter. The numerals below the line show the corresponding actual storage as a percentage of the full capacity of the tank.

To illustrate, assume a tank of 20,000-gallons gross capacity, and 96 in. diameter. If 24 in. of water is pumped in, the H/D fraction is 24/96=0.25. Corresponding to 0.25 *above* the scale bar the actual storage shown below the bar is only 0.2 or 20 per cent of full capacity--i.e., 4000 gallons. Since the tank was less than half full, the inner numerals were used. Similarly, if it is desired to fill this tank to 70 per cent of gross capacity locate 0.7 *below* the scale bar and the corresponding value of .665 for H/D will be found in the *upper* line. That is to say the tank must be filled to 66.5 per cent of its depth or .665 x 96 = 64 in. (approximately) above the bottom. In this case the outer numerals are used.



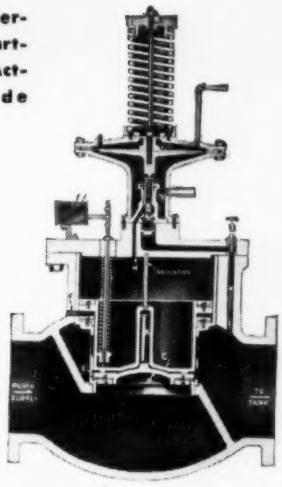
Pressure-Storage and Fill-Capacity Relations in Pneumatic Tanks

Golden-Anderson Single Acting Semi-Throttling Altitude Valves.



For New Construction or Rehabilitation

Golden-Anderson Stop Starter Single Acting Altitude Valves.

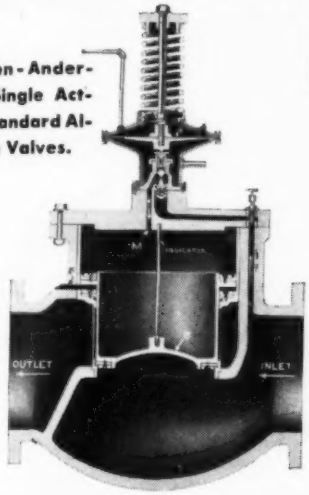


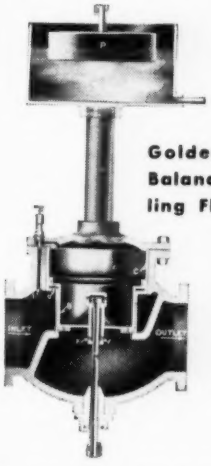
STANDARDIZE ON

GOLDEN-ANDERSON VALVES

for Engineered Protection

Golden-Anderson Single Acting Standard Altitude Valves.





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Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

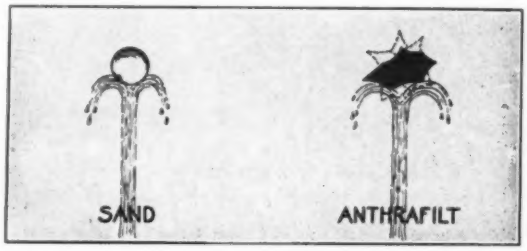
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effectixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

ANTHRAFILT AND ITS SIGNIFICANCE*

By H. G. TURNER

Research Engineer, Anthracite Equipment Corp.

ANTHRAFILT is a filter medium made from Pennsylvania anthracite. The first step in its preparation is the selection of a type of raw material which will provide a particle free from small fracture cracks and possessing the best form. This particle must be strong enough to withstand years of backwashing without breaking into smaller grains and should be sharp, angular and flat.

After the highest quality of raw coal is selected it is sent to the breaker where it is crushed, thoroughly washed and cleaned by gravity separation methods which free it from slate and associated non-coal mineral substances. The crushed material is finally screened over vibrating screens equipped with jets of water which assist in producing the desired size and remove, as far as possible, all very fine particles.

No one standard size is made in the screening process. Instead, different sizes are made to meet the various conditions of water treatment, water characteristics, filter design and filter operation. Information as to the best size for a given installation is obtained through a questionnaire sent to each purchaser. The purchaser who has had no experience with Anthrafilt should accept the specifications of the manufacturer regarding the proper size to be used. The manufacturer can make one size as cheaply as another so has no reason, other than the satisfactory operation of filters, to recommend one size in preference to any other. No filter expert, regardless of his years of experience or standing in the profession, can say with assurance what size Anthrafilt should be used in a filter unless he has conducted his own tests on this material under proper conditions in the laboratory or in the field. The reason for this will be made clear as this thesis is developed. These remarks all apply to the sand-size Anthrafilt. The sizes that are used in place of gravel are made to standard dimensions and are used in much the same way as gravel.

Properties of Anthrafilt Versus Sand

Sand is composed almost entirely of silica. It is insoluble in most acids but is soluble in alkalies. Its specific gravity is 2.65, and weight approximately 100 lb. per cu. ft. The particle shape is commonly rounded.

Anthrafilt is composed of carbon plus a small percentage of ash-forming mineral matter. It is not soluble in common acids or alkalies. Its specific gravity is 1.60 and weight approximately 50 lb. per cu. ft. The particle shape is sharp, angular and flat.

While it is true that silica sand and Anthrafilt have many other characteristics than those given, these are the ones of greatest significance in their contrasting behavior in filters.

Filters act both as strainers and as entrapping agents. Where no coagulant is used, the strainer action predominates. Where coagulants are used, entrapment predominates. Since the degree of entrapment is directly proportional to the surface area of the filter medium, the angular particle of Anthrafilt is more efficient than the same sized sand having a spherical shape, because an angular grain has a greater surface than a sphere of the same volume.

In practice, this means that a coarse Anthrafilt particle will give the same degree of turbidity removal as a relatively fine sand. This is important when one considers that a coarse filter medium, in contrast to a fine one, will give longer runs between backwash periods, will not clog as readily with algae, will develop lower head loss, will permit higher rates and will be cleaned more thoroughly when backwashed.

Since coarse Anthrafilt (±0.75 mm. effective size) is as efficient as fine sand (±0.40 mm. effective size) in turbid matter removal and since it weighs half as much, it can be substituted for fine sand without sacrificing the quality of effluent and without detracting from a high degree of filter bed expansion when backwashed with the same velocity as used with fine sand.

Users of Anthrafilt have found that it is more readily cleaned under routine backwashing. This has been strikingly demonstrated by Paul Weir of Atlanta, Ga., who made intensive turbidity determinations on the wash water discharged to sewer in the case of parallel experimental sand and Anthrafilt filters. In every determination the turbidity of the waste water from the Anthrafilt filter was higher than it was in the sand unit. This behavior is partly due to the particle shape and partly due to the composition of the Anthrafilt grains. Because of its dominant carbon content, Anthrafilt does not react chemically with the turbid matter which envelops the grain during filtration. Hence it not only releases common dirt easily but also does not become badly coated with lime, manganese or iron. With proper filter design and operation it will not coat even where lime-soda softening is used and only very slightly in iron removal filters.

Where the hot-process, lime-soda softening is used, Anthrafilt,[1] after the first few days of operation, will contribute no silica or other mineral matter to boiler feed water. Sand, on the other hand, will release silica to the water flowing through the softening unit.

The properties of Anthrafilt have made it very effective in filters of all kinds—filters for removal of oil, boiler treatment filters, swimming pool filters, chemical filters, iron removal filters, sewage filters, portable filters where light weight is important, and municipal filters of gravity, pressure or slow-sand type.

Historical Data

The first filter for clarification of municipal water was a slow sand filter built in London, England, in 1829. This filter was cleaned by scraping the surface and removing the upper portion of the sand for washing. In 1856, Tours, France, built the first filter to be backwashed. Since it was impossible to obtain enough pressure to lift the sand, this system of cleaning was abandoned.

The rapid filter was an American invention which was installed in industrial plants around 1883. This type of filter was first employed in the treatment of a public water supply at Somerville, N. J., in 1885. Up to this time little attention had been given to coagulation. From 1885 on the use of coagulants became a widespread practice. Sedimentation basins were given no serious consideration until several years after coagulation came into the picture. In all early filters the efficiency of the units was rated on bacterial removal. Chlorination had not yet become a recognized practice. Sand sizes, filter depths and filtration rates were all designed to give a clear water under these crude conditions of water treatment and filter design.

This historical sketch is cited to show that we may have inherited rules and regulations which no longer apply in view of filter improvements in many directions. The most outstanding relic of those early days is the commonly accepted filtration rate of 2 gpm. per sq. ft. for rapid filters. There have been great improvements in sedimentation basins, coagulation, chlorination and filter design, and yet the presently accepted filtration rate is the same as it was in the days before coagulation, chlorination or sedimentation. This does not seem logical.

There is adequate evidence that a filtration rate considerably in excess of 2 gpm. per sq. ft. is possible. As far back as 1898 Fuller reported successful filter operation at rates as high as 3 gal. In his "Report on Investigations Into the Purification of the Ohio River Water at Louisville, Ky.," he states: "But it is probable, in view of the results of the Western pressure filter, that in practice under favorable conditions the plant could be operated so as to make increased (uniform) rates in a measure meet increased demands for filtered water." In the same report he states further: "In all these systems the provision for subsidence, both with and without coagulation, was thoroughly inadequate."

As an example of more recent evidence, it has been reported that a total 4-gal. rate is used through sub-surface as well as surface filtration at the Kenilworth, Ill., filter plant.[3] While the rate is 2 gal. through the top of the filter and an added 2-gal. sidewise rate below the upper 2 in., the total vertical rate for the lower half of the filter is 4 gpm. per sq. ft.

About 1940 the Lansing filtration plant[2] was operating at a 3-gal. rate. The St. Louis (Howard Bend) plant is also designed to operate at a 3-gal. rate. The most recent installation is the new Chicago filtration plant[4] designed to operate at a 4-gal. rate during the summer and a 3-gal. rate during the winter. In addition, many plants are operating more or less subrosa at a 3-gal. rate.

In all the recent filtration plants designed to operate at higher than a 2-gal. rate, flocculators are used and some form of agitation or surface wash is used in the filters. Furthermore, at these plants more than average attention is given to the formation of a large, or at least a tough, floc particle.

The Part Played by Anthrafilt in Increasing Filter Capacity

The first municipal filtration plant to increase its capacity through the use of Anthrafilt was the Passaic Valley Water Commission plant at Little Falls, N. J.[5] Fig. 1 shows how the

*Published in the *Jour. A. W. Wks. Assn.*, 36, 431 (1944). Reprinted by permission of the Association.

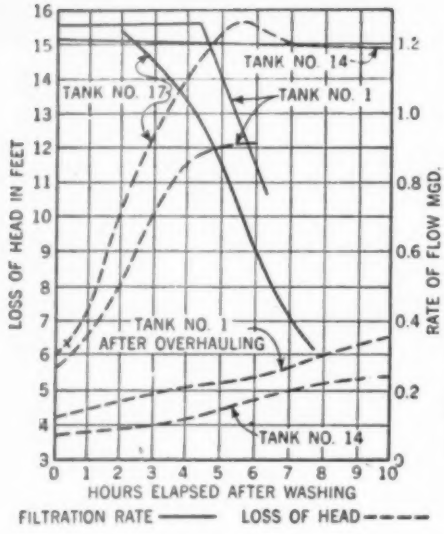
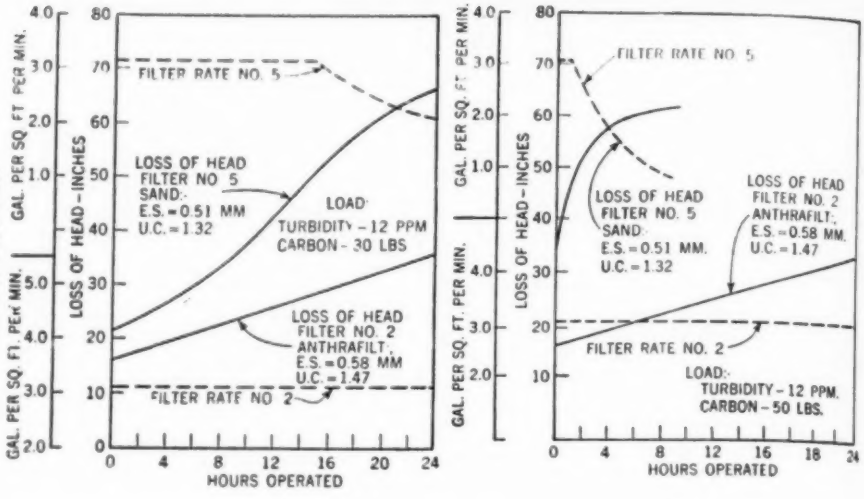


*Fig. 1. The First Municipal Filtration Plant (Passaic Valley, N. J.) to Use Anthrafilt to Boost Its Filter Capacity Showed a 50 Per Cent Increase.**



Figs. 2-3. Better Than a 3-Gal. Rate Is Maintained for 24 Hr. by Anthrafilt Units at Wilkinsburg, Pa.†

capacity of these filters was increased at least 50 per cent. The solid lines indicating the filtration rate show that Anthrafilt in tank No. 14 maintains its rate with little change over the full length of run, while in the sand tanks Nos. 1 and 17 the flow drops off rapidly within 2 to 4 hr. Air wash was used in these filters. The next municipal plant to use Anthrafilt to increase plant capacity was New Toronto, Canada, where capacity has been increased 100 per cent. At about this time the plant capacity of Oklahoma City, Okla., was increased from 16 mgd. to 30 mgd. by substituting Anthrafilt for sand.

Within the last year the Pennsylvania Water Co. at Wilkinsburg, Pa., because of excessive war demands, was forced to increase its capacity (Figs. 2 and 3). It will be noted that better than a 3-gal. rate is maintained for 24 hr. by the Anthrafilt units but it decreases rapidly in the sand units. With the filters not greatly loaded (Fig. 4) both Anthrafilt and sand hold their higher rates for the duration of the run although the Anthrafilt develops a much lower head loss. Palmer filter agitators were used.

Figs. 5 to 8 are photographs of 7-day loss-of-head charts from the filters of the city of Buffalo, N. Y. It will be noted that the Anthrafilt filter (Fig. 5) shows a filter wash once during the week; the sand filter (Fig. 6) shows two washes during the week. In Fig. 7 the Anthrafilt filter had to be back-washed twice a week during the algae season while the sand filter (Fig. 8) had to be washed 14 times. Palmer filter agitators were used in the Anthrafilt filter.

Many industrial plants have increased their filter capacity through the use of Anthrafilt plus recommended mechanical alterations. The best example of what has been done in an industrial plant is the experience of the Hammermill Paper Co. at Erie, Pa. A few years ago they doubled the capacity of their filters by changing from sand to Anthrafilt and installing Palmer filter agitators. This industrial plant is chosen because they filter 25 mgd. as compared with 30 mgd. for the entire city of Erie (population 127,000) and because they make a product of such high quality that their water must be close to perfect.

The author is firmly convinced that any filtration plant that is now operating at a rate of 2 gpm. per sq. ft. can increase its capacity by 50 to 100 per cent by taking one or all of the following steps:

1. Conduct laboratory tests to determine what kinds and what amounts of chemicals are necessary to secure the best floc under all conditions.
2. Make provision for quick mixing of chemicals with raw water.
3. Use pre-chlorination.
4. Improve flocculation by installing flocculators.
5. By means of floats or color solutions, test basin to locate short circuits. Install or remove baffles to counteract short circuits.
6. Compensate for reduction in sedimentation time and hence overloaded filters by installing surface wash if other forms of adequate sand surface agitation are absent.
7. Change from fine sand to coarse Anthrafilt of the proper size to meet the conditions. Coarse, water-worn sand will not be effective. Crushing vein quartz might work but it would require twice the wash-water velocity for backwashing.

In general, filter runs between washes should continue as long as a satisfactory effluent is produced but not beyond a period where the filter can be cleaned by backwashing. Anthrafilt will give filter runs at least twice as long as sand and still not load the filter to a point where it cannot be cleaned by backwashing. Georgia[4] obtained experimental runs of 300 hr. in an Anthrafilt unit at the Cornell University filtration plant. He says, however, that "...it is not believed to be good practice to put this much load on the filter. Runs have now been reduced to one week and they may be cut even more if future operation makes this seem desirable." There are probably many filtration plant superintendents who would not complain if their filter runs were reduced to one week.

Loss of head is a convenient indicator that a filter has run long enough. It should be correlated, however, with the quality of the effluent and conditions of filter, and should not be used as an arbitrary figure. The loss of head in Anthrafilt is rarely over 4 to 5 ft., whereas sand filters, under the same conditions other than filter medium size, will show a head loss of 9 ft. or more.

Size of Filter Medium and Filter Depth

One of the best papers on this subject was prepared by Thomas M. Riddick.[7] Much of the value of his paper is found in a discussion by several experts. In the same Journal is a paper by G. B. McCall, S. E. Edwards, and Edward S. Hopkins.[8] After reading these papers one can arrive at as many different conclusions as a handful of citizens interpreting a paragraph

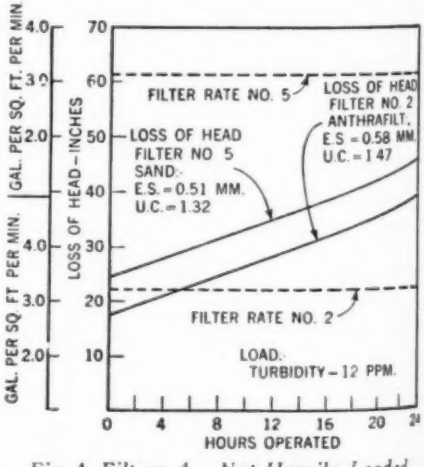


Fig. 4. Filters Are Not Heavily Loaded Both Anthrafilt and Sand Hold Higher Rates for Duration of Run at the Wilkinsburg Plant.†

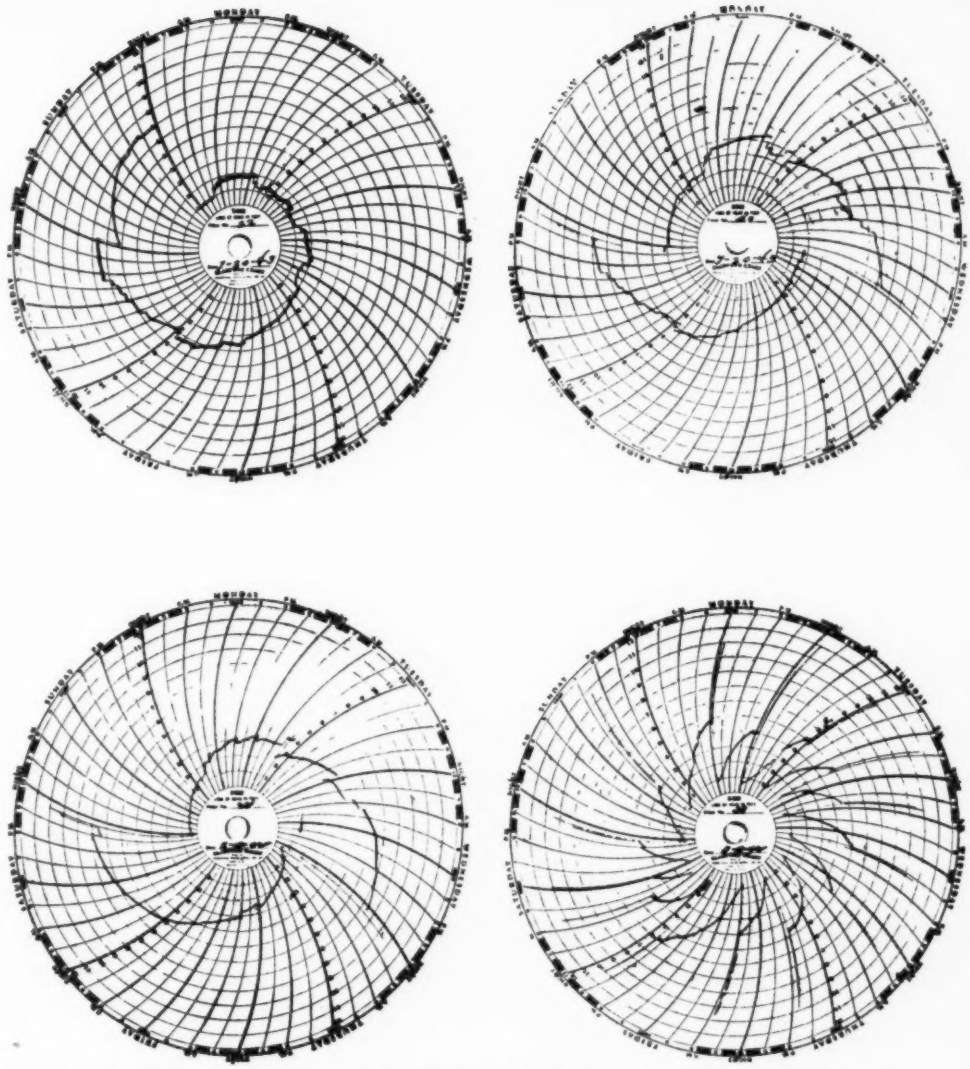
*Courtesy Arthur T. Cook, Gen. Supt. and Engr., Passaic Valley Water Com., Paterson, N. J.
†Courtesy R. B. Adams, Chief Chemist, Pennsylvania Water Co., Wilkinsburg, Pa.

in a standard government order. One thing on which the authors agree is the importance of proper conditioning of water for filtration. This is important because the selection of sand or Anthrafilt sizes and depths, to meet the worst conditions during the year, may impose expensive operation costs for 350 days of that year.

Another cause for confusion in such discussions is an attempt to supply small laboratory filter results to actual large filters or to apply findings from a filter of one type to one of different design. If these results are related to a large filter using high-velocity wash and high freeboard, they will not apply to a filter without troughs or low freeboard or to low-velocity wash plus agitation during washing.

In our own experimental work with Anthrafilt and sand it was found that a flat, angular grain was more effective in turbidity removal than a rounded grain. We agreed with all other investigators that the deeper the filter the coarser the filter medium could be. In applying our results it was decided that particle size and filter depths should be specified to suit the conditions of treatment, filter design and filter operation of each plant in question.

In most of our installations the Anthrafilt has an effective size of 0.70-0.73 mm. and a uniformity coefficient of less than 1.60 with a filter depth of 30 in. When a depth of 18 to 20 in. is all that can be placed in a filter the size is decreased to 0.58-0.62 mm. effective size. Where depths greater than 30 in. are available the size is increased accordingly. These general measurements are often modified to meet special conditions.



Figs. 5-8. Charts Show 7-Day Loss-of-Head From the Filters of the City of Buffalo, N. Y. (Courtesy Henry Wagner, Chief Chemist, Div. of Water, Buffalo, N. Y.)

Filter Wash—Length and Strength

Fixing a length of time for filter washing is like fixing a length of time for washing hands. Three minutes may be plenty for hands that rock the cradle but entirely inadequate for hands that grease motors. Filters should be washed long enough to clean them—which means a short wash if they are not very dirty and a long wash if they are filthy.

The wash water velocity required to clean a filter should be high enough to give nearly 50 per cent expansion if water wash from below is used exclusively. If adequate agitation during washing is available, a low-velocity wash is effective and of course a relatively low expansion of filter bed.

Anthrafilt filters are usually washed with a 24-in. rise during the winter and a 30-in. rise during the summer. Where filter agitation is available, wash water velocities of 18 in. rise per minute, even for the coarsest material, have been found adequate. There will be no greater loss of Anthrafilt than of sand during the life of a filter. While Anthrafilt is half as heavy as sand, the weight of the individual particle is not half that of ordinary sand because a coarser particle of Anthrafilt is used.

One cause of dirty filters is the feeling that it is a disgrace to lose filter medium. A plant may use several carloads of alum per year without disturbance and yet if a little sand is washed from the filters it is the basis for criticism. The filter operator is usually instructed to use great care in washing the filter so as to lose no sand, and, as a result, commonly underwashes. If he were instructed to be certain to wash filters so as to lose 5 per cent of the sand per year, the filters would be kept in a much cleaner condition. Two filtration plants in a large industrial city may be cited as examples: At one plant no sand has been purchased for 23 yr. and the filters are full of mud and cracks. At the other plant one carload of sand is purchased each year and the filters are very clean. Where filters are provided with means for effective agitation of the material during backwashing, no sand loss is likely to occur.

Summary

Since Anthrafilt is essentially a carbon, and hence more nearly chemically inert than any other filter medium, it is well suited for many filtration processes. Its conchoidal fracture produces a particle which has the most desirable shape for use in filters; its low specific gravity and angular shape makes possible longer filter runs and more effective filter washing at lower backwash rates. Filter capacities have been increased from 25 to 100 per cent through the use of Anthrafilt.

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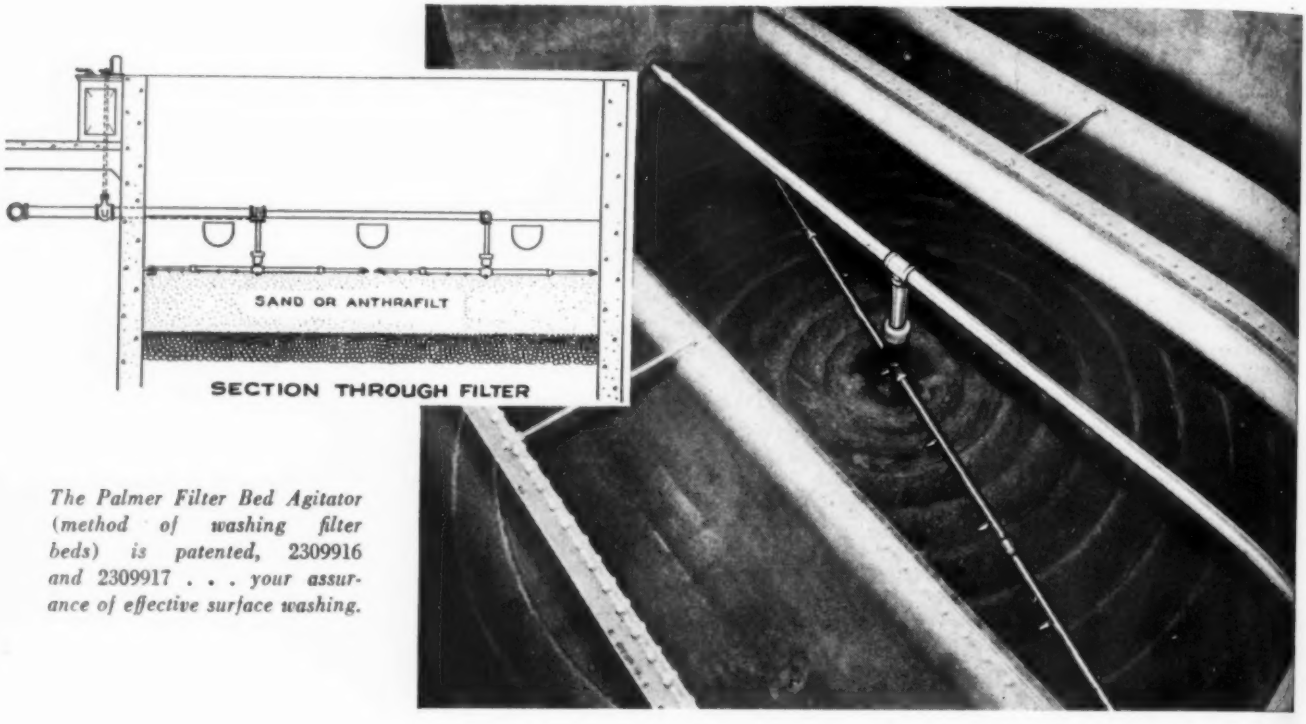

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FILTER WASHING

Some Observations on and Results with Methods Old and New

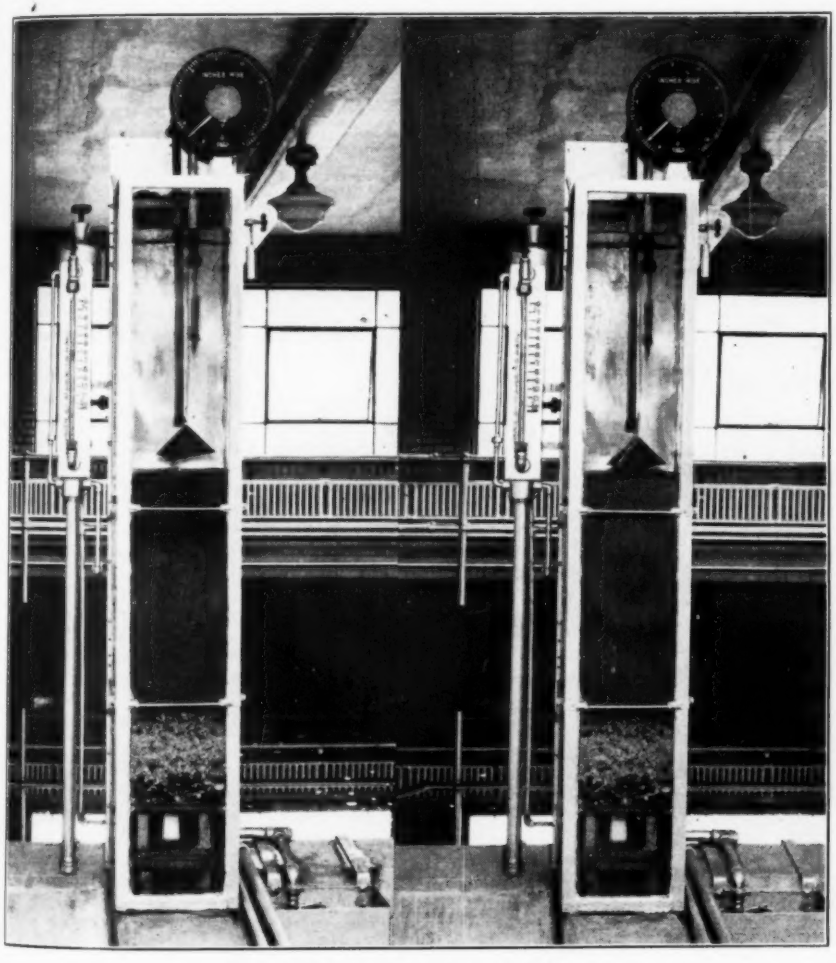
By H. J. KRUM, Supt. of Filtration and I. M. GLACE, Consulting Sanitary Engineer
Allentown, Pa., and Harrisburg, Pa.

THE authors of this paper, although having no official connections, have nevertheless cooperated for years on the solution of the many difficulties incident to the proper maintenance of public water supplies and the collection and disposal of sewage, including certain research and operating problems. The care of filters, naturally, has been one of the matters considered.

This association has been unusually beneficial to both authors and the more effective, it is felt, because one author (Krum) has had available a large and well equipped laboratory for chemical and bacteriological studies and, as chief operator of a ten million gallon rapid sand filter plant as well as several smaller swimming pool filters, has been able to install for experimental purposes many devices of varying kinds, and to put into practice a number of improved operating procedures.

Although the authors confess to differences of opinion on some of the practices of the profession, they find themselves in complete agreement on the desirability of better facilities for the cleansing of the media of filter units, and on the efficiency of the socalled surface-wash.

The data and conclusions presented herein represent a consolidation of ideas and opinions based on detailed research at one plant and on general observations at plants over a wide area.



The Allentown Experimental Filter.

Fig. 1 (left) shows the layer of coated top sand after many repeated washings at high rate bottom wash alone.

Fig. 2 (right) reveals the result of sand scour secured by surface-jet wash for only a short period.

The hanging cone is the sand bed expansion indicator developed at Allentown for indicating correct washing rates throughout the year.

Past Practices

For the sake of clarifying this discussion, and in an attempt to indicate briefly the struggle of the profession to solve this knotty problem of filter operation, the historical outline which follows is cited to show approximately the time periods in which certain designs and practices have been popular in the water works field:

—Prior to 1910—

In circular tub filters; with false bottoms, pipe laterals, a variety of types of strainer heads and, commonly, revolving fixed rakes, with "low" wash water rates of 8" to 12" rise per minute.

1910 — 1920

In rectangular concrete units; with slightly increased wash water rates, and frequently air wash as an auxiliary.

1920 — 1930

As in 1910-1920, but with "moderate" rates of wash up to about 30" rise, and with perforated lateral pipes and deeper gravel beds for better distribution.

1930 — 1940

As in 1910-1920, but with "high" rates of wash up to 48" rise per minute, a variety of filter bottoms, many of a nonmetallic character, and frequently false bottoms to replace manifolds and laterals.

Surface wash was introduced as an auxiliary to the bottom wash, with either fixed or revolving piping at the surface of the medium for such purpose. The introduction of porous plate filter bottoms, eliminating the gravel bed.

Seemingly most of the difficulties in filter washing began with the advent of the rectangular concrete box filter. This period coincided with the abandonment of the circular wooden-tub type filter and mechanical rakes.

The time periods indicated are, perforce, only approximations and considerable overlapping naturally occurs in any such classifications. As for instance, perforated pipe laterals were used as early as 1905, at the Harrisburg, Pa., works.

Mention should be made of the use of slat-bottomed units which, generally, have never been accepted by the profession because they seem to violate one of the basic principles of design; that is, the production of a uniform head at the base of the strainers, or other openings through restricted orifices.

Mention might be made, also, of the use in a number of plants of fine mesh screens, installed between the top of the gravel layer and the sand bed to prevent "upsetting" of the gravel; a condition which, it is not generally recognized, exists to some extent in practically all units not in some way protected against disturbance. This point in the filters—the junction of the sand and gravel—might well be classed as the "danger line," since a serious upset at this junction of the two media results finally in the failure of the bed to perform its functions and, ultimately, in the necessity for a complete and expensive overhauling of the affected unit. The seriousness of this problem brought forth the development of the porous-plate false bottom, a very promising improvement in design.

In addition to the listed methods of construction, an enormous amount of time and effort has been given to a study of the sizing and specific gravity of the filtering media, resulting, from a design standpoint, in the use of anthrafilt in many filters, and the use of coarser sands of a larger effective size.

All of this — revolving rakes, air wash,

false bottoms, screens as gravel retainers, "high" rates, and what not, even when combined with greatly improved mixing and coagulation of chemicals—has not resulted in the design or use of any one "best" procedure, or in the prevention of mud-balls, hard spots, and the necessity for the frequent expesive overhauling of the units; nor has it provided operators with means for maintaining a really *clean* filtering medium.

It is admitted that in some of the more carefully designed and better operated plants these interferences in filtration have been held to a minimum but so far as the water works field generally is concerned, the results are stated above.

High Wash Rates Disappointing

Of these various features of design, the so-called "high" wash rate seems to have been the greatest disappointment and the most misleading. A rise of as much as 48" per minute is exceptional but when this is expressed, as it might well be, as 4 feet per minute, the actual low velocity of such a flow can be more readily recognized. Although the actual velocities through the interstices of the expanded sand may be 2 to 3 times this stated velocity, but little sand scrubbing effect results.

The Surface Wash

Various forms of surface wash have been developed in the last half dozen years (not considering the old revolving rake in this classification) with almost universal improvement in operation.[1, 2] The development of the relatively inexpensive and easily installed Palmer Filter Bed Agitator has speeded up the trend towards such a form of auxiliary wash since it was introduced to the field in 1939, and first described by the inventor, a filter operator, in this magazine.[3]

The success of these various forms of surface wash is the result of the relatively high velocities of the jets issuing from the distributor arms, which velocities commonly reach from 50′ to 100′ per second, or 1,000 times that of the socalled "high rate" bottom wash. The tremendous scouring action of these fire stream velocities is at once apparent.

Some Allentown Observations

When Hulbert and Herring[4] first directed the attention of the profession to the importance of the degree of expansion of the sand bed in filter washing and emphasized the higher efficiency of the more viscous low temperature water, in expanding the media, the authors became interested in the importance of wash water control to secure effective bed expansion under all conditions. To this end Krum, in cooperation with the Simplex Valve and Meter Co., developed the sand expansion indicator, now used successfully in many plants. Data on these studies was first published in WATER WORKS AND SEWERAGE.[5]

For the Allentown experiments a model filter unit with glass sides was constructed. It had an effective area of one square foot and was built to full vertical scale. It was equipped with the perforated concrete Leopold bottom, a duplicate of the block originally installed in the Allentown plant. In other words, the experimental unit is an exact replica of a 12-inch square section of the full size filters—see Fig. 1.

Sand for the experimental unit was taken from one of the plant filters, using a perpendicular column of sand extending from the surface down to the gravel layer. The sand at the bottom of this column had the appearance of clean sand, but the top 8 inches was black in color and had a coating of impurities, approximating 20 per cent by weight. This experimental bed was washed repeatedly, probably 200 or 300 times, at wash rates which expanded the sand in varying degrees up to 60 per cent.

During the course of these experiments on the rate of expansion no new sand was added to the filter; nor, although the unit is equipped to receive coagulated and settled water, was such water applied to the unit. The coated condition of the top sand at the end of the repeated high rate washings in these experiments is revealed in Fig. 1. In the photograph it has the appearance of a layer of black water rather than sand.

At the conclusion of these expansion experiments a fixed jet surface wash of the Baylis type, shown in Figs. 1 and 2 as a perpendicular pipe extending downward and ending 3 inches above the top of sand bed, was installed in the experimental filter to determine whether or not the coating on the sand grains could be removed by this method of washing. The results were startling. The application of the high pressure water jets to the unexpanded sand created a violent movement in the top 8 inches of the bed. This scoured the sand so effectively that the supernatant water immediately became opaque because of the turbidity, and was black in color. After two minutes of this initial scouring of the settled bed, wash water was introduced from below and the entire bed of sand expanded 50 per cent. The resulting downward movement of the upper sand, due to the action of the surface jets, and contact with the upward movement of the lower sand due to the back wash, caused a second violent scouring, with a penetration to 18 inches below the surface. Repeated washing of the sand in the experimental unit by this method resulted in the disappearance of the black coating on the top sand, and the entire volume of sand attained the appearance of uniformly clean sand, as revealed in Fig. 2.

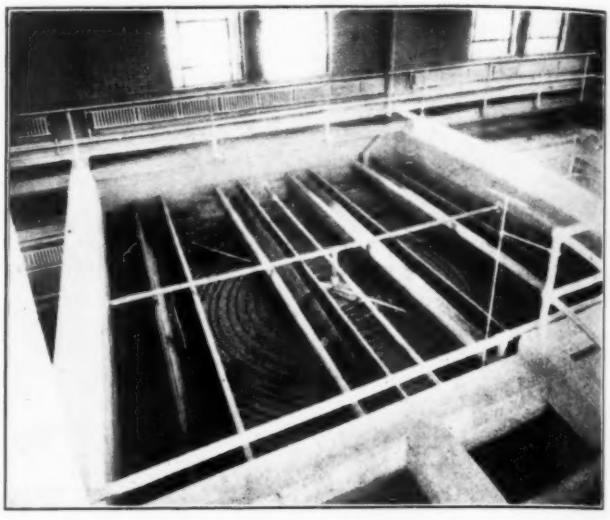


Fig. 3—One of the 1.25 M.G.D. Filters Equipped with Palmer Revolving Agitators.

This demonstration convinced the authors of the comparative inefficiency of the normal method of washing filters. Observations, in other plants have simply confirmed this conviction and further convinced us of the comparative inefficiency of the normal method of washing filters.

Full Plant Scale Data

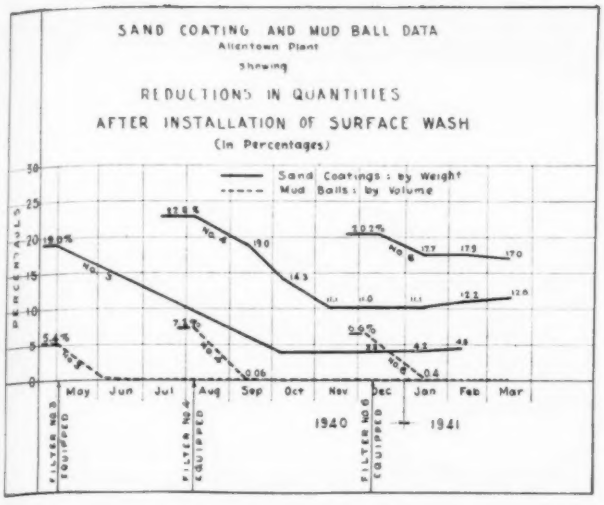
The Allentown filter plant was built in 1928 and takes water from the Little Lehigh River, a stream draining a fertile farming area, with consequently widely varying turbidities. The works comprise an intake well with screens, low lift pumps, a baffled mixing basin, with an actual retention period of about 20 minutes for floc formation, duplicate sedimentation basins of about 2 hours capacity, and 8 rectangular filter units with a capacity of 1.25 m.g.d. each. Alum is used as a coagulant, with pre- and post-chlorination. The only unusual features of the plant are the non-metallic Leopold Duplex Filter Bottoms. The raw water alkalinity is above normal for Pennsylvania and somewhat hard, but is not grossly contaminated. Some few industrial wastes in minor quantities are present in the water.

The history of the Allentown filter units is typical of many other plants, with probably an average amount of mud ball formation, some gravel disturbance, and an occasional hard spot at the outer perimeter of the units and in the corners. Since the plant was built in 1928 the sand has been ejected from the filters twice for the purpose of breaking up mud balls and to examine the condition of the gravel layers.

Conditions at Allentown, the authors feel, average the field quite generally except for the absence of troubles commonly due to metallic bottoms. The plant is operated at full rates with daily shutdowns of several hours each day.

After due consideration of the condition of the filters and other factors involved, and because of the results observed in the experimental filter, a rotating Palmer Filter Bed Agitator was installed in filter No. 3 in April, 1940. The results were so satisfactory, from a visual standpoint, that four additional filters were equipped with Palmer Agitators, the first being installed in July, 1940, and the last two in April, 1941. The remaining three filters in the plant are likewise to be equipped before the end of 1941.

The surface dimensions of the Allentown filters are 20 feet by 22 feet. The Palmer Agitator installed consists of one brass unit with properly placed jets and with an overall length of 19½ feet, the longest arm used anywhere, according to the manufacturer, up to the time of the last installation. In order to provide rigidity for the agitator, sections of galvanized pipe 2½ inches



Graph 1—Sand Coating and Mud Ball Records (Revealing Rapidity with Which Surface Wash Removes Sand Coatings and Clears Out Mud Balls)

in diameter in the form of a cross are fastened to the four walls of the filter with wall flanges—see Fig. 3.

Mud Ball and Coating Reductions

Before the second installation was completed in August, 1940 (filter No. 4), samples of sand were taken from the top 6 inches of the bed and the volume of mud balls accurately measured, using the method advocated by Baylis.[6] In addition, the amount of coating on the sand grains was determined by treating a weighed sample with concentrated hydrochloric acid, washed, dried and reweighed.[7]

These determinations have been repeated monthly since that time. It will be noted in Table 1 and Graph 1 that the average amount of mud balls in the top 6 inches of the seven filters not equipped with agitators was 5.6 per cent. In filters No. 3 and 4, equipped with agitators, after one month of service practically no mud balls remained.

TABLE No. I

Filter	% Mud Balls	Sand Characteristics — Eff. Size	Uniformity Coef.
No. 1	4.3	.63	1.35
No. 2	4.6	.53	1.32
No. 3	0*	.60	1.50
No. 4	7.2	.53	1.40
No. 5	8.3	.55	1.36
No. 6	6.0	.55	1.36
No. 7	2.9	.54	1.40
No. 8	6.1	.69	1.30

*Not tested previous to installation of Palmer agitator. Tests—October 29, 1940.

Unfortunately, no sand coating test was made on the sand in filter No. 3 prior to the installation of the agitator. However, the average coating on the sand in filters No. 4, 5 and 6 before the installation of the agitators was 23.4 per cent. The rate of reduction in sand coating, as the result of surface scouring, is shown in Graph 1, which tells its own story better than can be told in many words.

Wash Water Savings

The authors are unable to confirm claims made by others as to marked savings in wash water through the use of surface wash, either by careful analysis of the Allentown plant data or after more general observations elsewhere. It is conceded, however, that other operators may have collected information demonstrating success in this phase of the operations where filter design may not have been as satisfactory—as at Allentown.

At Allentown it has been the practice to wash each filter unit at a loss of head of 6 feet, or immediately upon the appearance of turbidity in the effluent of such filter, rather than to depend entirely on the loss-of-head rate-of-flow, or time period, as variously and generally practiced. Successful coagulation and sedimentation, as well as the turbidity of the raw water, under Allentown procedure greatly affect the length of filter runs. Data on filter runs at the Allentown plant for the year 1940 are shown in Graph No. 2. The effect of spring and fall rains is reflected in the shorter runs in April and November.

In a study of these filter run figures, consideration should be given to the fact that the sand in the plant has been in use for 12 years, and that considerable variation exists in the sizes and uniformity coefficients in the various units because of the gradual and non-uniform loss of the finer particles.. The possible effects of these sand characteristics has not as yet been studied in detail.

An examination of the graph on filter runs reveal no definite trend in filter run time, nor does it indicate any reasons for a failure to secure longer runs. The general average of the agitator-equipped filters is approximately that of the other units. The high percentage of wash water used for filters No. 3 and No. 4 in the first months after installation of the agitators in these units, undoubtedly was due to frequent washing for demonstration and experiments, rather than to normal procedure.

From the standpoint of increased length of filter runs, therefore, no savings in wash water have been secured at Allentown. The same general impression seems to have been arrived at in other plants under observation, without any definite figures available for confirmation. A lower sand expansion index has been used at Allentown in the agitator-equipped units than in those not so equipped, but the saving in wash water which apparently should be effected has not been confirmed by actual measurement and plant data.

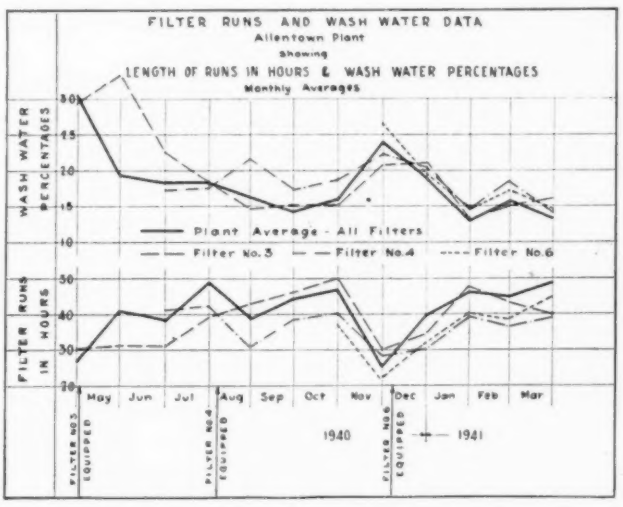
At Allentown, as previously stated, prechlorination is a regular practice. One of the gains effected through the surface wash installations and a further indication of the increased cleanliness of the media in the units so equipped has been the greater residual chlorine maintained in the effluents of these filters, as compared with the effluents of the remaining filters. Data are shown in Graph 3.

Chlorine Economy

It will be noted that the chlorine residuals in the effluents are uniformly and consistently greater for agitator equipped units No. 3, 4 and 6 than for the other units not so equipped. On many occasions the residual of these units has shown very little reduction from that of the residual of the applied water. In actual practice this means eventually a decrease of appreciable amount in the rate of application of pre-chlorine, with subsequent savings in expenditure for this chemical when all filters have been equipped with surface wash facilities.

This effect of the cleaner sand on chlorine residuals (chlorine absorption by the bed) was first noted in December, 1940, some six months after the first agitator was installed in filter No. 3 and three months after No. 4. Detailed studies and observations on the residuals of the separate units was then begun and have since been continued.

The heavy chlorine demand of the average filter unit is well known, and it is sometimes difficult to secure any residual chlorine through a filter bed unless the sand is super-chlorinated before pre-chlorination is begun, or until heavy pre-chlorination has been practiced for some considerable period of time. As a matter of fact, many an operator has been brought to grief through the application of pre-chlorine to dirty filters because of subsequent severe taste and odor production resulting from reactions between

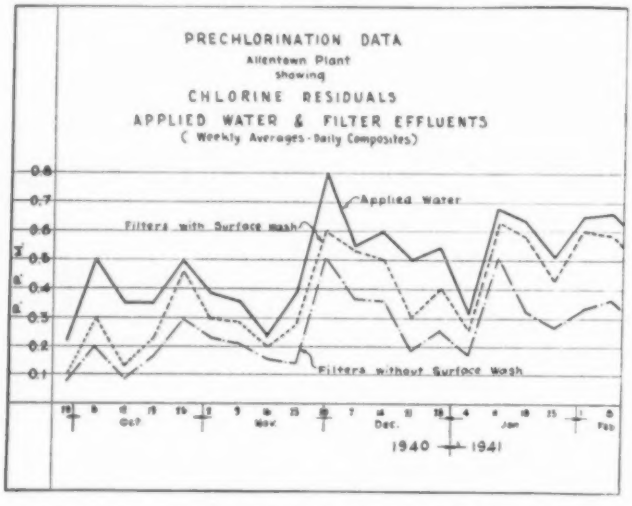


Graph 2—Filter Run and Wash Records (These Records Fail to Show Wash Water Reduction Accruing from Surface Wash at the Allentown Plant)

the chlorine and accumulations within the ineffectively washed sand bed.

At Allentown all filters were thoroughly chlorinated before pre-chlorination was begun. Prior to the time the first agitator was installed, application of chlorine in doses up to 1.14 lbs. per million gallons had been used continuously for approximately 12 months, with the point of application at the influent of the mixing chamber, approximately three hours before the chlorinated water reached the filters.

The decreased chlorine demand of the filtering media after the agitators were installed became apparent almost immediately in filter No. 6, and after about two months of operation, the residual of this unit reached approximately the same figures as for those



Graph 3—Records of Chlorine Removal by the Filters (Indicating the Extent to Which Chlorine Is Absorbed by Coated Sand vs. Clean Sand in Those Filters Equipped with Palmer Agitators—in Itself an Index of Sand Cleanliness as Well as an Operating Economy Realized)

of filters No. 3 and 4, which had been surface washed for about 6 months and 4 months, respectively, prior thereto.

The authors hope to make a detailed study of this problem—the chlorine demand of filter media—in the near future.

Costs of Installation

The effective apparatus of the agitators, consisting of a toggle joint, pipe manifold, and special nozzle openings, all of brass, was purchased at a cost of $197.64 for each unit at Allentown. Auxiliary valves and pipings were purchased by the city and installed by the salaried employes of the city. Basing the labor costs, however, on current hourly rates for skilled mechanics, and adding in the costs of piping, valves, etc., the total cost of installation for one unit (1.25 m.g.d.) was $310. This would mean a total cost of about $2,500 to equip all eight filters in the plant.

In this cost analysis, consideration must be given to the fact that the Allentown filter boxes are almost square in plan (20 by 22 feet), so that it was possible to use only one revolving mechanism to each unit. With filters of dissimilar area, the costs may be greater because of the necessity for installing two or more arms in each bed to cover the entire area. Apparently a reasonable average cost figure, for general use, might be given as $350 per M.G.D. of filter capacity.

Summary

1. To a greater or lesser degree, mud-balls and hard spots are common to rapid sand filter units.

2. Despite careful design, careful operation, and a multitude of practices, no generally successful method of preventing these disturbances had been found prior to the development of the surface wash by Baylis about 1930.

3. In all plants where surface wash has been made an auxiliary to normal bottom wash, improvements in the appearance and cleanliness of filter media have been made.

4. Surface wash piping or the revolving Palmer agitator can be installed without any major interference with normal filter operation.

5. Costs of installation of the Palmer Agitator depends on the size and shape of the filter boxes, but generally speaking, should average about $350 per M.G.D. capacity, including all costs for labor and appurtenances.

6. At Allentown, Pa., with a Palmer Agitator to provide surface wash:

a. Mud balls were practically eliminated in five weeks' operation of a full scale unit.

b. Coating on sand grains was materially reduced.

c. No appreciable saving in wash water has resulted through the use of surface agitation.

d. With pre-chlorination, the effluent of agitator equipped filter units show continuously higher chlorine residuals than do the units washed at high rates but without surface agitation.

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7. Krum; Jour., Penna. W. Wks. Operators Assn., Vol. 10, 1938.

PAINTING DAMP WATER PIPES

In reply to a question regarding the painting of plant piping which is wet from condensed moisture and cannot be taken out of service long enough to dry, The New Jersey Zinc Company prints the following in its periodical, "Paint Progress." The engineer, by the way, stated that wiping the pipes with dry rags before painting had not been satisfactory.

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"The turpentine has a two-fold effect: first to replace the water remaining on the surface by virtue of its preferential wetting property, and second, to 'lift' any loose rust scale remaining on the surface after the mechanical cleaning. A primer coat of standard Zinc Dust-Zinc Oxide paint is then applied directly on the turpentine wet surface, thus providing the necessary rust inhibitive coating. In actual practice, a considerable interval may be allowed between the application of the turpentine and the primer, since the turpentine prevents further condensation of water on the steel.

"Brush application of the primer is preferred to spray application, since it insures the intimate contact of the Zinc Dust with the surface. An 80:20 Zinc Dust-Zinc Oxide formula with a linseed oil vehicle has been used, but a synthetic vehicle, such as phenolic, may be preferable, first, because of the more rapid drying of the synthetic resin formulation, and second, because of the improved water resistance of the film.

"The usual drying interval is allowed, after which the finish coat paint is applied. Just before the application of the second coat, the moist surface is again wiped with turpentine, but care must be taken to avoid an excess of the turpentine, since it might soften the surface of the primer.

"Either an 80:20 Zinc Dust-Zinc Oxide paint or other suitable metal paint may be used as the finish coat. Colored Zinc Dust paints are available for finishing coats where a distinctive color scheme is desired.

"It has been found that kerosene may be substituted for turpentine to replace moisture on the pipes, but its action is much slower and its assimilation into the paint less positive."

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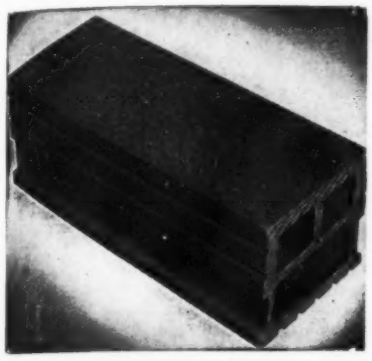

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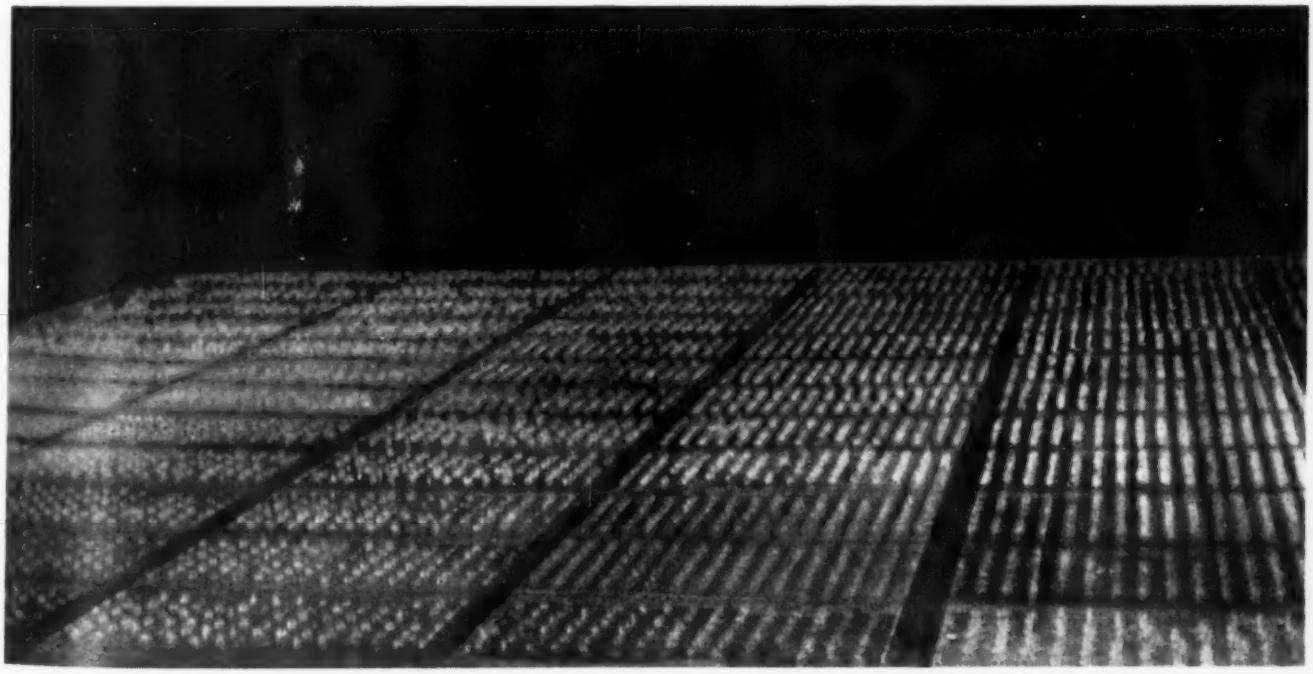

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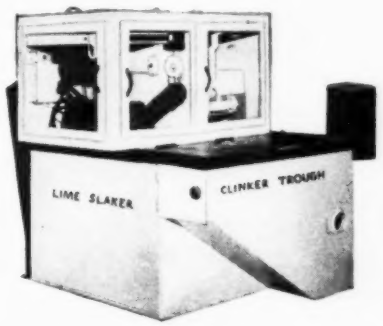

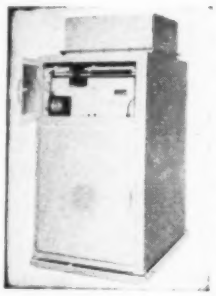

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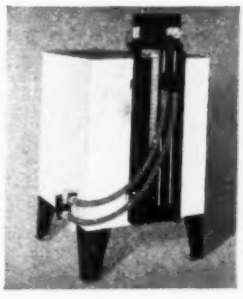

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THE CHEMISTRY OF WATER TREATMENT*

By A. P. BLACK
Professor of Chemistry
University of Florida, Gainesville, Fla.

PART I. COAGULATION

IT IS well for those of us who are engaged in any phase of water treatment to occasionally review the basic principles having to do with the processes being employed. These articles are prepared with that in mind. They do not purport to contain any material which is new or original and no references to the literature will be cited. They have been prepared with the idea of briefly summarizing the most important chemical principles underlying certain processes of the chemical treatment of water. Part I will deal with coagulation; Parts II and III with softening and corrosion control, respectively.

Coagulants may be defined as those substances which are capable of removing colloidal impurities from water, and coagulation is the process by which such removal is brought about.

As we look back over what has taken place during the past seventy-five years, it seems rather clear that the development of coagulation as an art was greatly influenced by the development of slow sand filters, the first of which was constructed in 1829 by James Simpson of the Chelsea Water Company, London. Its effectiveness for the purification of water is too well known to require discussion here. It was early noted that its efficiency was greatly improved after the formation on the surface of the sand of a slimy gelatinous coating which was and still is termed "Schmutzdecke." There seems little doubt but that when early American workers began their development of the rapid sand filter it was their desire to duplicate by chemical means this slimy coating or schmutzdecke on the sand.

Since a chemical was to be used, however, it had to possess certain qualifications. It must, first of all, be gelatinous in nature so as to resemble as nearly as possible the organic growths on the older slow sand filters. Furthermore, it must be non-toxic, it must be relatively inexpensive, and it must be capable of reacting either with water itself or with substances naturally present in water or which might be added to water so as to produce the necessary gelatinous precipitate. As we all know, aluminum sulfate or a filter alum was selected for study. Although many years have passed since alum was first used for this purpose, it is probably true to say that it is still the most widely used of all coagulants in water treatment.

It is the purpose of this paper to show that the remarkable properties of filter alum as a coagulant are not due to its gelatinous nature but to entirely different properties unknown to the earlier workers. It is one of the most remarkable coincidences in contemporary science that after the real mechanism of coagulation became known, filter alum still remained the most widely used of its class.

*Condensed from lectures given at the Short School for Water and Sewage Works Operators offered jointly by the Georgia State Board of Health and the Georgia Institute of Technology, Atlanta, Georgia, in Sept. 1947.

It is possible to write equations for the chemical reactions which take place when aluminum sulfate is added to water containing natural alkalinity or added alkalinity in the form of lime or soda ash. These are shown below:

1. $Al_2(SO_4)_2 \times H_2O + 3\ Ca(HCO_3)_2 = 2\ Al(OH)_3 + 3\ CaSO_4 + 6\ CO_2 + (X-6)H_2O$
2. $Al_2(SO_4)_3 + 3Ca(OH)_2 = 2\ Al(OH)_3 + 3\ CaSO_4$
3. $Al_2(SO_4)_3 + 3\ Na_2CO_3 + 6\ H_2O = 2\ Al(OH)_3 + 3\ Na_2SO_4 + 3\ CO_2$

While it is probable that there are cases where these reactions take place essentially as they are written, it is also probable that there are many cases where they do not go about it in exactly this manner. In order to understand that statement and the true mechanism of coagulation, it is necessary to examine the nature and properties of colloids.

Colloids, Their Classification and Properties.

The colloidal phase refers to any form of matter in a certain state of subdivision or, better, within certain limits of particle size. The unit of measurement to be used is the millimicron or mμ. This is one-millionth (0.000,001) of a millimeter, which is approximately one twenty-five millionth of an inch. While no definite limits may be set within which various phases of matter may be grouped, it is possible to state that the molecules and ions of true solutions usually vary in diameter from 0.1 to 1 mμ. The particles in the colloidal phase will usually fall between 1 mμ and 100 mμ; above the higher figure they merge into the suspensions and emulsions which may be separated more or less readily by physical means.

A solid or particle size between 1 and 100 mμ when dispersed in a liquid is called a suspensoid, and a liquid the droplets of which vary in diameter from 1 to 100 mμ when dispersed in another liquid is called an emulsoid. Both are colloids. In most respects colloids resemble true solutions; in ordinary lighting they are clear and transparent, they will not settle, and they may be filtered without removal of the colloidal material. Under proper lighting conditions, however, a bright beam of light passed through a colloidal solution produces what is called a "Tyndall Cone" which results from the reflection of part of the transmitted light by the tiny particles. Under the ultra-microscope colloidal particles are found to be in constant motion. This motion, termed the "Brownian movement," results from the bombardment of the tiny colloidal particles of the colloid by the rapidly moving molecules of the solvent. The boiling point, freezing point, osmotic pressure and vapor pressure of colloidal solutions are essentially identical with those of the pure solvent.

Colloids may be classified in a number of ways. In the first place, they may be classified as sols or gels. Sols are, of course, colloids which have the appearance of true solutions, whereas gels have a jelly-like structure from which the name colloid (Greek: Like glue) was derived. Sols and gels may be readily demonstrated by anyone by two simple experiments. For the first experiment, one takes two 1-liter beakers, one containing boiling distilled water and the other distilled water just above the freezing point. If to each beaker there is added two or three drops of a saturated solution of ferric chloride a most interesting contrast will be noted. The beaker containing the cold distilled water will exhibit only the very faintest color of the dissolved ferric chloride, hardly perceptible to any except the trained eye; the other beaker, however, assumes a deep wine-red color. The explanation of course is that at the temperature of boiling point the ferric chloride is hydrolized with the formation of colloidal ferric hydroxide and soluble hydrochloric acid. This ferric hydroxide sol is crystal clear and may be filtered through the finest laboratory filter paper unchanged. If the cold beaker be set aside for a few hours or over night, it will gradually color up until the same wine-red intensity is finally reached. If both are allowed to stand for a few days a reddish gelatinous precipitate of ferric hydroxide will result in each. This is due to the fact that other ions present in the solution will finally cause precipitation. If, however, these colloids are dialized and these foreign ions removed, the colloidal solution will be stable almost indefinitely. The writer has in his possession and has many times shown colloidal solutions of ferric hydroxide, of metallic silver and metallic gold, which are at the present time fifteen years old and which have maintained their strength essentially unchanged during that period.

Another simple experiment may be used to demonstrate the formation of a gel. In one beaker is placed 30 ml. of a clear saturated aqueous solution of calcium acetate. In a second beaker there is measured out 170 ml. of 95% ethyl alcohol. If now the alcohol is rapidly poured into the clear limpid solution of calcium acetate and then an attempt is made to pour the mixture back into the first beaker, it will be found that the mixture has set to a solid gel before the transfer can even be begun. This gel is so stiff that it may be penetrated by the finger only with difficulty, yet it is formed within a matter of moments from two clear free-flowing solutions.

Colloids may be classified as reversible and non-reversible. Ordinary starch solution is an excellent example of the former. If a little starch is added to boiling water and the mixture boiled for a few minutes, a clear, faintly bluish solution results. When allowed to cool it sets to what is termed "starch paste." However, if reheated it will again assume the appearance of a solution. Egg albumin or ordinary egg white is an excellent example of a non-reversible colloid. A small amount of fresh white of egg added to water and thoroughly shaken yields what appears to be a true solution. If now this mixture is boiled the egg white is coagu-

lated and it may not be again transformed to its original state since a permanent change in the material has taken place.

Colloids may be classified as lyophobic and lyophyllic. This classification has to do with the affinity of the colloidal particles for the dispersing medium. If the attraction between the colloidal particles and the dispersing medium is small, the colloid is termed lyophobic. If, on the other hand, the attraction between the colloidal particles and the dispersing medium is great the colloid is termed lyophillic. The viscosity of lyophobic colloids is usually about the same as that of the medium, and they are quite susceptible to coagulation. The viscosity of lyophillic colloids, on the other hand, is usually much greater than that of the pure medium. In water treatment we deal for the most part with lyophobic colloids.

Finally the most important of all, colloids may be classified as positive or negative since it may readily be shown that they bear electrical charges. There are a number of theories as to the source of this electrical charge, but these are beyond the scope of this discussion. It is sufficient for us to know that the particles of some colloids bear a positive charge whereas the particles of other colloids bear a negative charge. It is also true that colloids may be prepared in essentially neutral condition and it is further necessary to note that colloids may change their electrical charge from positive to negative or the reverse as a result of a change or changes in external conditions. The latter point is very important in the theory of coagulation since it has been shown by numerous workers that both aluminum hydroxide and ferric hydroxide flocs may be either positive or negative. This has a most important bearing, not only on floc formation, but also on the completeness with which a coagulant will do the job it is supposed to perform.

Methods of Precipitating Colloids.

Colloids may be precipitated in a number of ways. Three will be mentioned since each of these has found applications or plays a part in water treatment.

The first is by electro-phoresis. This rather involved word simply means the precipitation of a colloid of one sign on an electrically charged pole of opposite sign. As a specific example, if we immerse two electrodes in the beaker of ferric hydroxide sol whose preparation was described earlier in the paper and pass a direct current through the sol, the wine-red color may be observed to slowly drift toward the negative electrode and a precipitate of gelatinous ferric hydroxide forms on and below that electrode. Since the colloidal ferric hydroxide particles have moved to the negative pole we may assume that before they were neutralized they bore a positive electrical charge. There are, on the other hand, various colloids which when placed between charged electrodes will move to the positive pole. These, of course, are negative colloids.

It is interesting to remark at this point that the two types of impurities for which coagulation is most commonly employed, namely color and turbidity, are both present in water in the form of negative colloids. This point is emphasized since it is most important in the discussion to follow. During the past few years a number of devices employing this principle of electro-phoresis have been suggested for practical use under various trade names. They have not been particularly successful due to polarization of the electrodes and frequent cleaning which is necessary.

Colloids may be coagulated by other colloids of opposite sign. For example, if to a negatively charged colloidal sol there is added an equivalent quantity of a positively charged sol, something akin to neutralization takes place and a precipitate is formed which consists of the mixture of the two substances originally present. This is most important in connection with coagulation of a water and will be referred to again later.

In the third place, and most important of all, colloids may be precipitated by ions of opposite charge. For example, if to a stabilized ferric hydroxide sol bearing a positive charge a little hydrochloric acid is added, the sol will be precipitated by the negatively charged chloride ion. This is the explanation for the ultimate precipitation of the ferric hydroxide hydrosols whose preparation has been described. There is, however, a very great difference in the relative precipitating power of ions and this power results from the value of the charge carried by the ion. Keeping in mind that in a discussion of this sort, only very general statements can be made, it is possible to say that as a rule the precipitating power of a bivalent ion will be 50-60 times as great as a monovalent ion and the precipitating power of a trivalent ion will be 600-700 times as great as that of a monovalent ion.

It is this remarkable fact which throws most light on the action of soluble aluminum and ferric salts as coagulants in water treatment. It may be demonstrated by dividing a positively charged ferric hydroxide sol prepared as described above into three equal portions. To one there is added a small amount of sodium chloride. To the second is added an equivalent amount of sodium sulfate and to the third is added an equivalent amount of one of the soluble sodium ortho-phosphates. The sodium chloride will have very little effect in precipitating the sol, the effect of the sodium sulfate will be very much greater and that of the sodium phosphate greatest of all. If the experiment is carried on in such a manner that quantitative results will be obtained, values for the relative precipitating power of the ions approximating those just given will be obtained.

Having now reviewed some of the chemistry of colloids, we are in a position to examine the known facts of coagulation and to attempt to explain them in terms of the behavior of colloids. We have learned that both color and turbidity present in natural waters are present in the form of negative colloids. That leads us at once to the conclusion that for their coagulation we will need to employ either a positive ion or a positive colloid or both. As it happens both agents take place in the phenomenon of floc formation. We discover now by examining the chemical formulae for filter alum and ferric sulfate or ferric chloride that these coagulants each have a positive ion whose valence is three. Though chemists have carefully searched the periodic table of the elements and have made efforts to employ other elements of the same valence and elements of higher valence, it still remains true that these salts are most effective and most widely used as coagulants.

Mechanism of Coagulation and Floc Formation.

When a coagulant is added to water for the removal of color or turbidity three separate factors and three different types of action are involved. They will be discussed in the order in which they take place.

1. As the coagulant dissolves and the trivalent aluminum or ferric ions become available, they neutralize the negative charge on the particles of color or turbidity and, as we have seen, their neutralizing power is very great. This, in the opinion of most authorities, is the most important phase of coagulation and it takes place long before the visible formation of floc particles. It is evident that this action will be more efficient if the coagulant can be brought into intimate contact with the material to be removed before secondary reactions can take place. This clearly implies the desirability of rapid mixing as the first step in coagulation.

2. When the positively charged aluminum or ferric ions have neutralized a considerable portion, perhaps most of the negatively charged colloidal particles of color or turbidity, the resulting particles may be called micro-flocs for the purpose of this discussion since they are still beyond the limits of visibility and far too small to settle under the influence of gravity. Furthermore, it has been shown that, in the acid range of coagulation most commonly employed, they still retain positive charge, possibly due to the adsorption of positively charged hydrogen ions from the solution. We are now dealing, therefore, with a positively charged colloid which has the capacity to neutralize the negatively charged colloid. These positively charged micro-flocs can therefore continue to remove negatively charged particles of color or turbidity, and this constitutes the second phase of coagulation.

3. During both of the above phases no visible floc particles have formed. The mechanical treatment of the water from this point forward should consist of slow stirring, termed by some authors "conditioning" in order that these tiny micro-flocs may cluster together and agglomerate with the formation of floc particles which steadily grow in size until they are in a proper condition for sedimentation. During this phase of floc growth the third action, that of surface adsorption, takes place. It is outside the scope of this paper to deal with the various theories of adsorption, and the complex forces which may be and probably are involved. It is sufficient only to say that the amount of surface area exposed by the innumerable particles of floc is very great and that impurities in the water may be adsorbed on these active surfaces. It should be emphasized however that the formation of a large and well formed floc, while important from the standpoint of sedimentation, is not necessarily the criterion of successful coagulation since the most important functions of the coagulant take place, as has been shown, before the floc ever attains visible size.

Influence of Other Ions Present in Water.

It has been stated that the micro-floc particles formed by coagulation with either filter alum or ferric sulfate in the acid range bear a positive charge. This has an important implication to the water chemist since it should mean that a water high in sulfate ion should be coagulated more readily than a water low in sulfate ion or high in chloride ion and that is

true. While the precipitating power of the bivalent negative sulfate ion is not as great as of a trivalent ion it is still very high and it is true that sulfate waters are more readily coagulated in the acid range than are chloride waters, and for the same reason ferric or aluminum sulfate are better coagulants than the corresponding chlorides. It follows also that since the ions are charged, each ion present in a given water will have some effect on floc formation, the positive ions in the water interfering with the formation of a positive floc and the negative ions helping in its formation. This is one of the important reasons which explains the individuality of waters as far as their coagulation is concerned. As will be shown in the next paper in this series, the softening of water by any of the known processes follows well defined chemical laws and dosages, and results can be calculated in advance. This is not true with coagulation. The first of the chemical equations which has been listed above presents what would happen if filter alum reacts completely with natural alkalinity present in a water. Assuming for filter alum a "practical" molecular weight of 600, which corresponds to about 14.5 molecules of water of crystallization, one grain per gallon of alum would reduce the alkalinity of a given water by 8.5 parts per million. If pure aluminum sulfate whose formula is $Al_2(SO_4)_3 \cdot 18\ H_2O$, and whose molecular weight is 666 be used, then the theoretical reduction in alkalinity by one grain of alum is 7.7 parts per million. Every water works operator who is experienced in coagulation is, however, well familiar with the fact that it is possible to add a considerable dosage of alum to a water with alkalinity reduction substantially less than called for by either of these figures. This indicates the correctness of the theories of coagulation which have been set forth above and results from the fact that a considerable fraction of the aluminum ions instead of reacting with the alkalinity of the water react directly with the negatively charged particles of color or turbidity.

In the case of organic color, the flocs formed are called "color flocs" and are quite different in properties and appearance to the gelatinous aluminum hyroxide formed by the reaction of aluminum sulfate with alkalinity in water. Although this is true, it has not been found possible to arrive at equations for calculating the amount, which will hold in every case, for a given coagulant to remove a given amount of color or turbidity from a water. Such equations are published from time to time and are usually valid for the particular water from whose treatment they are derived but as a rule they are found not to hold in case of other waters. This can only mean of course that we do not as yet have sufficient information with regard to the true nature of the colloidal impurities which we are removing from water. This is particularly true with respect to organic color. After more than fifty years of water treatment, we still find ourselves in the position of using more or less rule-of-thumb methods for the removal from water of a material about whose chemical composition we know relatively little. Much research needs to be done on the fundamental nature of color in water.

Coagulants Used in Water Treatment.

It is hardly worthwhile to attempt a complete listing of the coagulants which have been used in water treatment since most water works men are familiar with them and they receive frequent mention in the literature. As has been previously stated, aluminum sulfate continues to be the most widely used material of its kind but there appears to be an increasing tendency toward the use of ferric sulfate. Sodium aluminate often finds application, particularly in industrial water treatment. Ferric chloride and chlorinated copperas have been used and in the Middle West a combination of ferrous sulfate and lime is widely used, mainly for the removal of turbidity. It was one of the first coagulants to be used in this country, having been used by Bull in Quincy, Illinois, in 1898.

The use of Bentonite has been suggested but it has not been generally adopted although it has proved useful in certain cases. The use of activated silica as an accessory coagulant deserves special mention. A solution of sodium silicate, activated with sulfuric acid as recommended by Bayliss, by aluminum sulfate as recommended by Graf and Schworm, or by ammonium sulfate, chlorine, carbon dioxide, and so forth as recommended by Hay and others, yields a stable sol bearing a high negative charge. In the acid range it effectively promotes coagulation and floc formation with either aluminum sulfate or ferric sulfate. It is not generally recognized, however, that activated silica may act as a coagulant in the truest sense of the word since, in softening many waters by the lime-soda process it results in the formation of a better-formed and better-settling sludge than either alum or ferric sulfate. The new 80-million gallon softening plant of the City of Miami is being designed to employ activated silica as the only coagulant although facilities will be provided for feeding alum to anticipate possible changes in water quality. In the case of this particular water a dosage of 2-4 parts per million of activated silica yields better results than a dosage of three grains per gallon of alum. While activated silica used in conjunction with another coagulant should properly be called a coagulant aid, the time has come to recognize that it may and often does act as a coagulant in the truest sense of the word.

Laboratory Control of Coagulation.

The most important single tool at the disposal of the chemist in charge of the operation of a coagulation plant is the jar test machine and there is no substitute for numerous and properly conducted jar tests for the control of such plants. Only by such test can the most economical dosage of coagulant be arrived at and the best settling flocs be obtained. There are many excellent papers in the literature describing the proper technique for such tests and they are also described in several of the contemporary text books and manuals. Every operator who does not have a jar test machine and is not using this test, should consult these references and institute such tests if he desires to obtain best results from his plant. Along with the jar test it is necessary to make regular and periodic determinations of color or turbidity, alkalinity, total hardness and pH value. The latter is especially important since it has to do with the stability of the treated water. In the case of most so-called "Filter" plants which employ coagulation, the treated effluent is apt to be quite soft and of relatively low pH value. There are a number of ways by which such waters may be stabilized and that subject will be discussed in one of the other papers which are to follow.

The ever-increasing popularity of the newer types of up-flow equipment emphasizes the need for a better understanding of coagulation since retention times are far less in these types of units than in the older and more conventional settling basins. For the same reason a great deal more vigilance and careful supervision is indicated in the operation of such plants. It is doubtful if anywhere in American chemical industry there is to be found a comparable example of the use of chemicals in the tonnages consumed by the water works industry and in the dilutions employed by it. The chemical reactions, not only of coagulation but of softening as well, are carried out in extremely low concentrations, and it is a tribute to the ingenuity, resourcefulness and scientific ability of the water works man that they are so successfully employed under these unusual conditions.

PART II. SOFTENING

The past few years have witnessed a large increase in the production of softened water. There are two main reasons for this increase. In the first place, new industrial processes have created a demand for large volumes of soft water. In the second place, there is an increased appreciation on the part of the average domestic consumer of both the aesthetic advantages and the economic savings resulting from the use of soft water. The result has been that whereas a few years ago water softening was practiced very largely only in so-called "hard water" areas, it has now spread to all portions of this country and throughout most of the world.

Lime-Soda Process

There are two main processes employed for the softening of water. The first is the lime or lime-soda process and the second is the zeolite process. They will be discussed in the order named, but before discussing the chemistry of water softening, it is necessary to pause for a moment to consider the types of hardness present in natural waters. In the first place, hardness in water is due to its content of calcium and magnesium. It is rare that any other ion is present in sufficient quantities to be seriously considered in softening calculations or practice. The calcium and magnesium salts are present in one or more several forms. When present as bicarbonates or normal carbonates, the hardness so resulting is called carbonate hardness. When present in the form of sulphates, chlorides, or nitrates, the hardness so resulting is called noncarbonate hardness. As we shall see, each type hardness requires a different treatment for its removal.

Reactions in Lime-Soda Process

1. $CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$
2. $Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$
3. $Mg(HCO_3)_2 + Ca(OH)_2 = CaCO_3 + MgCO_3 + 2H_2O$
4. $MgCO_3 + Ca(OH)_2 = Mg(OH)_2 + CaCO_3$
5. $MgSO_4 + Ca(OH)_2 = Mg(OH)_2 + CaSO_4$
6. $CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$
7. $CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$

The equations listed above show all the reactions which take place in softening a water containing both carbonate and noncarbonate hardness by the lime-soda process. It will be noted in equation 1 that carbon dioxide is shown being removed by lime. It

should be noted that carbon dioxide is not considered to be hardness in water but when present it will consume lime in direct ratio to the carbon dioxide content and since it must be considered in calculating the cost of softening and the chemical dosages required, it is shown first among the softening reactions.

Equations 2, 3 and 4 show the removal of carbonate hardness by lime. It will be noted that whereas only one molecule of lime is required for each molecule of calcium alkalinity, two molecules of lime are required for each molecule of magnesium alkalinity. It follows, therefore, that high magnesium waters require a higher dosage of chemicals than waters low in this element. Equation 5 shows the removal of the magnesium non-carbonate hardness by lime. It will be noted that no softening is effected by this equation since for each molecule of magnesium salt present an equivalent amount of calcium salt is formed.

Equations 6 and 7 show the removal of non-carbonate hardness by soda ash. The equations are identical but are written twice since equation 6 shows the removal of calcium sulphate formed in equation 5 and equation 7 shows the removal of calcium sulphate originally present in the water. From these reactions it will be noted that an equation to be used in calculating the dosage of lime necessary to soften a given water should contain three terms, one for carbon dioxide, one for carbonate hardness and one for magnesium.

Calculation of Lime Dosage

1. Ppm. 100% CaO = (CO_2 + carbonate hardness + magnesium) × .56
2. Ppm. 90% CaO = (CO_2 + carbonate hardness + magnesium) × .62
3. Ppm. 100% $Ca(OH)_2$ = (CO_2 + carbonate hardness + magnesium) × .74
4. Ppm. 90% $Ca(OH)_2$ = (CO_2 + carbonate hardness + magnesium) × .82

Calculation of Soda Ash Dosage

5. Ppm. 58% light soda ash = (non-carbonate hardness − X) × 1.06

Many types of equations have been proposed and employed for calculating the dosages of lime and soda ash required for softening a given water. Those shown above are simple and have the advantage of referring back directly to the equations which have just been given. Equations 1 and 3 are of theoretical interest only since it is not possible to purchase 100 percent pure calcium oxide or calcium hydroxide but they are shown since that clearly indicates the source of the equations themselves.

In using the equations, carbon dioxide, carbonate hardness and magnesium must all be expressed in terms of calcium carbonate. This means that the carbon dioxide content in parts per million, determined as such, should be multiplied by 2.28 and the magnesium content in parts per million, determined as such, should be multiplied by 4.11. The carbonate hardness will have already been determined and expressed in terms of calcium carbonate. The figure .56 is the molecular weight of calcium oxide expressed as a percentage and the equation shows that it requires only 56 percent by weight of pure calcium oxide to remove a given weight of the constituents included in the equation when they are expressed as calcium carbonate.

In equation 2 the figure .62 is merely a factor corrected for the purity of commercial quicklime and where large shipments are involved and accurate analyses are available, the actual figure obtained by analysis should be used in place of that given. In the same way, in equation 3 the figure of .74 is the molecular weight of hydrated lime expressed in per cent and the equation shows that 74 per cent by weight of 100 per cent pure hydrated lime will remove a given quantity of the constituents shown in the equation. The figure .82 in equation 4 is a correction based upon hydrated lime containing 90 per cent $Ca(OH)_2$. Here again actual percentages should be used if available.

These equations are capable of numerous modifications since it may not be necessary or desirable to remove all of the carbonate hardness or all of the magnesium. In recent years so-called selective softening has assumed considerable importance, the term indicating only the removal of calcium hardness, all of the magnesium hardness being allowed to remain in the water except a small percentage brought down by occlusion in the calcium carbonate sludge.

Equation 5 provides a method for calculating the dosage of soda ash required to remove non-carbonate hardness. The "X" in the parentheses stands for the carbonate hardness which may be allowed to remain in the softened water and still yield a final treated water of the desired total hardness. For example, if it is desired to soften a given water so as to have a total hardness of 85 parts per million and the alkalinity of the softened water is found to be 40 parts per million, then 45 parts per million of non-carbonate hardness may be allowed to remain in the water and in such cases X = 45 ppm. When the first four equations are compared with equation 5 it will be noted that whereas the amount of lime required to remove a given amount of carbonate hardness is substantially less than the weight of carbonate hardness removed, in the case of non-carbonate hardness the weight of soda ash required to remove a given amount of hardness is about 6 per cent greater than the weight of hardness removed. The figure 1.06 is the molecular weight of pure sodium carbonate expressed in per cent and no corrected equation is necessary since 58 per cent light soda ash is about 99 per cent pure sodium carbonate.

The equations indicate, therefore, that it is more economical to soften waters of low magnesium hardness than waters of high magnesium hardness and it is likewise more economical to remove carbonate hardness than non-carbonate hardness since the cost of lime in either form is very much less than the cost of soda ash. Having calculated the dosage of lime and soda ash required in parts per million, it is only necessary to convert to pounds per million gallons and multiply by unit cost to secure the figure for the cost of softening per million gallons.

Chemicals Employed

Lime is used in one of two forms, hydrated lime or quicklime. Hydrated lime is usually shipped in fifty-pound paper bags as a finely ground powder and is most suitable for use in small plants because of its ease of handling and feeding. Quicklime, on the other hand, may be shipped in bags, barrels or drums, but is usually shipped in bulk cars and must be stored under carefully controlled conditions. It must be slaked and fed by special slaker-feeders.

Slaking is usually carried on at a temperature of 150 degrees F. to 165 degrees F. and the hot milk of lime resulting from the slaking process is delivered to the softening basins. Soda ash is usually shipped in one hundred-pound paper bags and the material known technically as "58% light soda ash" should be specified. The Committee on Specifications for Water Purification Chemicals has in preparation complete specifications covering each of these materials and these specifications will soon be available to the profession.

Since a part of the sludge formed in the softening operation is of such particle size as to approach the colloidal state and settles with difficulty, if at all, it is usual practice to employ a small amount of some suitable coagulant in connection with lime or lime-soda softening. For this purpose alum or a ferric salt may be employed and usually a dosage of 0.5 grains per gallon or even less is satisfactory.

The last three or four years have witnessed the widespread use of "activated silica" as a coagulant in a lime or lime-soda softener. Sodium silicate activated with ammonium sulphate was first used for this purpose in Fort Lauderdale, Fla., nearly five years ago, replacing 4 grains per gallon of alum and effecting very substantial savings. There are at the present time in operation in Florida a number of softening plants employing activated silica as the only coagulant and the new 80 mgd. softening plant of the City of Miami is being designed for the use of sodium silicate activated with carbon dioxide as the coagulant.

This material has proved amazingly effective, particularly in the case of waters high in calcium and low in magnesium. The Miami water supply contains approximately 100 parts per million of calcium ion and only 4 parts per million of magnesium. Dosages of alum as high as 3 grains per gallon have little effect on settling softened water where as little as 2 parts per million or ⅛ grain per gallon of activated silica allow a settled water going to the filters having a turbidity of approximately 5 parts per million. Although activated silica was originally suggested by Baylis as a coagulant aid, it is suggested by the writer that the multiplying cases where the material is used as the only coagulant now make it possible to designate it as a true coagulant in every sense of the word. There is not time in this brief paper to go into the possible mechanism of its action except to say that it is not as yet completely understood and that conflicting theories still prevail.

Mechanical Equipment Used

In the early days of lime softening, "fill-and-draw" plants were common and three such plants were constructed in the State of Florida. They consisted simply of basins which were filled with water, chemicals added, the mixture of water and chemicals mixed with compressed air from 45 minutes to one hour, and then the softened water allowed to settle for 12 to 18 hours. The clear settled water was then pumped to surface without filtration or stabilization. Two of the three Florida plants of this type have been abandoned and the third has been modernized and converted to more efficient operation.

The next development consisted in the use of separate mixing basins followed by some type of clarifier or mechanical settling unit. The mixing basins are equipped with one of a number of different types of mixing equipment and in many plants facilities

are provided for the return of sludge. Water from the mixing basins passes to the clarifier where the settled water flows over collection weirs to recarbonation basins and filters and the sludge is pumped from the bottom of the unit, either continuously or at intervals as desired. These units have obvious advantages over the old type plants.

Recent years have witnessed the introduction of several types of "high rate" units so-called because the rate of flow through the units is far in excess of values employed in the older type units. Values for rate of rise of water in excess of two gallons per square foot per minute of effective basin area are now common so that it is possible to soften water in units which have an effective settling area less than the area required for the rapid sand filters, assuming that the conventional filter rate of two gallons per square foot per minute is employed. This is neither the time nor the place to introduce a discussion of the relative advantages and disadvantages of the various types of units available, but it is believed that the statement may be made that, in general, they represent a substantial improvement over old type equipment.

Limits of Softening

The theoretical limit of softening by the lime-soda softening process is, of course, the solubility of the resulting precipitates at the temperature employed. This value in case of a water containing both calcium and magnesium hardness, and assuming a dosage for the "complete" removal of both, is 25 parts per million but it is rarely, if ever, attained in cold lime-soda softening. In low magnesium waters it is readily possible to secure final alkalinities of 33-35 parts per million but as the magnesium content of the raw water increases, the alkalinity of the final effluent is apt to increase also, unless a considerable excess of lime is employed.

The economic limit of softening is, of course, set by the use to which the water is to be put. Since only a very small fraction of the water produced by a municipal water treatment plant is used for those purposes where hardness is a factor, it is obvious that there is a very definite limit of softening beyond which the economies effected will not pay for the additional cost. For many years it has been generally understood that this figure is approximately 85 parts per million; however, with the widespread increased use of domestic hot water systems, and the great increase in the price of soap, it is necessary in each individual case to re-evaluate this figure in the light of existing conditions and there appears to be a tendency toward softening municipal water supplies to a total hardness lower than 85 parts per million.

In the case of industrial waters, of course, the degree to which the water is softened will be set by the use to which it is to be put. For boiler use, hot process softening is very commonly employed. The theoretical basis for hot process softening results from the fact that the precipitates of calcium carbonate and magnesium hydroxide become less soluble with increasing water temperature. By softening at a temperature of approximately 200 degrees F. it is possible to reduce the hardness of the treated water to 7-10 parts per million. In connection with hot process softening, the use of dolomitic lime, magnesium sulphate or ferric sulphate also results in reducing soluble silica to very low values. This modification is being increasingly used in cases of waters to be used in high pressure boilers.

Sludge Disposal

The disposal of the sludge produced in softening plants may often present a problem. Where it is possible to transport the sludge in liquid form to an adjacent river or lake or an area of low ground to be filled, the problem is relatively simple. If, however, the plant is located in a built-up residential or industrial area, the problem is more difficult. Attention is more and more being given to the possibility of calcining water softening sludges to recover the lime. Where waters free from turbidity and low in magnesium are being softened this process has attractive possibilities, and Pedersen's work at Marshalltown, Iowa, is well worth studying. At Miami, Fla., there has just been completed the first large rotary calcining plant to handle water treatment sludges in this country and the second in the world. The plant, expected to go into operation late this year, has a capacity of 28,000 tons of quicklime per year.

Zeolite Softening

The zeolite method of water softening takes advantage of the remarkable property of certain naturally occurring aluminosilicates for base exchange; that is, these materials have the property of reversibly exchanging bivalent materials such as calcium, magnesium and iron for monovalent elements and ions such as sodium, potassium, and ammonium. The most common of these is the mineral glauconite, commonly called "green sand." The reactions of a natural green sand employing the sodium cycle are:

1. $2\,NaZ + Ca(HCO_3)_2 = CaZ_2 + 2\,NaHCO_3$
2. $2\,NaZ + CaCl_2 = CaZ_2 + 2\,NaCl$

The first reaction shows the removal of calcium bicarbonate or carbonate hardness by sodium zeolite and the second reaction the removal of calcium chloride or non-carbonate hardness by sodium zeolite. In each case the corresponding sodium salt appears in the treated water. Two factors are thus evident with respect to this cycle. The first is that since sodium bicarbonate will behave toward N/50 sulfuric acid exactly as will calcium bicarbonate, the alkalinity of zeolite softened water is unchanged. The second fact is that there is always an increase in the total dissolved solids of zeolite softened water since the two sodium ions weigh somewhat more than the calcium ion which they replace. In the case of high magnesium waters this increase in total solids is more pronounced since the weight of the sodium ion is almost double that of the magnesium ion which they replace.

In addition to natural green sands, several other types of zeolites are available. Natural green sand may be specially processed, resulting in a product usually known as "high capacity green sand." Zeolites may be made synthetically by either a wet or dry process and yield siliceous materials having all the properties of natural green sands but to a considerably greater degree as their exchange capacity is substantially higher than the natural products. Other types of zeolites in common use include the carbonaceous zeolites and the resin type zeolites. Carbonaceous zeolites may be made to function either as sodium zeolites or as hydrogen zeolites. In the latter case, the reactions are:

3. $2\,HZ + Ca(HCO_3)_2 = CaZ_2 + 2\,H_2O + 2\,CO_2$
4. $2\,HZ + CaCl_2 = CaZ_2 + 2\,HCl$

Here the calcium is replaced by hydrogen yielding, in the case of the bicarbonate ion, carbon dioxide and water, and in the case of calcium chloride or calcium sulphate, hydrochloric acid or sulfuric acid. Since carbon dioxide may be removed by aeration, hydrogen zeolites may be used to remove the alkalinity from water and substantially reduce the total solids. Since the free mineral acids produced by reaction of chlorides and sulphates with the minerals would be very corrosive, it is necessary either to add alkali to the treated water, or most usually, to bypass water containing sufficient natural alkalinity to neutralize the mineral acids formed in the fraction softened. These reactions are frequently made use of in boiler water.

Certain resinous types of zeolite have been developed which will completely absorb the mineral acids formed in the hydrogen cycle. Obviously, therefore, by first by-passing water through a hydrogen zeolite followed by passage of the same water through a resin type zeolite, all total solids except silica will be removed and a product which is essentially distilled water will be obtained. Recently, synthetic zeolites have been developed which will either remove silica completely or reduce it to very low values. The process is called "demineralization" and is being increasingly used by industry.

Regeneration of Zeolites

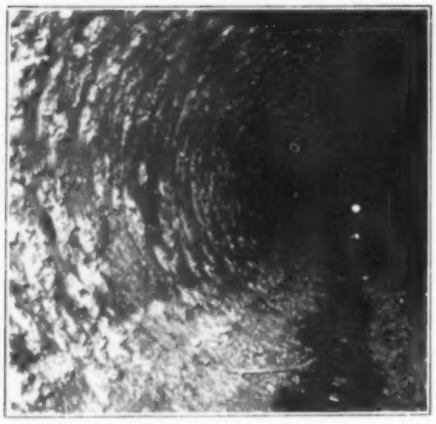
When the exchange capacity of a zeolite has been exhausted it is regenerated by use of salt brine in the case of sodium zeolite, of sulfuric acid in the case of hydrogen zeolite, and by sodium carbonate in the case of resinous zeolites which have been used to remove acids. The reactions are shown below:

5. $CaZ_2 + 2\,NaCl = CaCl_2 + 2\,NaZ$
6. $CaZ_2 + H_2SO_4 = CaSO_4 + 2\,HZ$
7. $Z \cdot H_2SO_4 + Na_2CO_3 = Z + Na_2SO_4 + H_2O + CO_2$

The cost of softening water by any of these processes will obviously be the cost of the regenerating material necessary to bring back the mineral to its original capacity after it has been used to soften a given volume of water. The exchange capacity of zeolites is ordinarily expressed in grains of hardness removed per cubic foot and materials in the same class may vary somewhat in their exchange capacity. The exchange capacity can also be influenced by the extent and method of regeneration. Natural green sands will usually remove about 3000 grains of hardness per cubic foot of mineral, high capacity green sands about 5000-5500 grains per cubic foot. Siliceous synthetic products have widely varying exchange capacities which depend upon the composition and method of manufacture. Their capacity usually varies between 6000 and 12,000 grains per cubic foot. In some cases, higher capacities are obtained, particularly for resinous types of zeolite.

Factors Affecting the Applicability of Zeolite Softening

There are several factors which affect the applicability of zeolite to the softening of water. In the first place, water passed through zeolite is softened to zero hardness and if a water of a specified hardness is desired, sufficient raw water must be bypassed to effect the desired result. Obviously, therefore, this process is not suitable for waters which contain turbidity, organic color or precipitated iron. Waters containing iron may sometimes be successfully handled by the zeolite process provided they are softened before aeration since the iron will be removed in the softening cycle.



Example of Tuberculation in 48 in. Steel Pipe

Special types of zeolites have been developed for the removal of iron and for other purposes but they cannot be discussed in the limitations of this paper.

Unless salt is available in bulk at moderate cost, the cost of softening water by the zeolite process usually exceeds that of the lime-soda process. The amount of salt required to regenerate zeolite mineral usually varies between 0.35 and 0.50 pound of salt per 1000 grains of hardness removed. Zeolite softening is far simpler from the standpoint of operation than is lime-soda softening and can readily be made completely automatic. For this reason it has been widely adopted for home softeners and for a great variety of industrial applications and there are a number of municipal zeolite softening plants in this country and abroad. Where natural brines are available either from the sea or from underground sources, the cost of zeolite softening is greatly reduced and zeolite softening with regeneration by natural brines will probably increase in the future in those areas where the process may be employed.

The most recent development in zeolite softening consists in the leasing to individual consumers of small portable units which are serviced and maintained constantly in operating condition by companies distributing such units. This development is spreading widely throughout the country and is attracting increasing favor, even in cities where municipal water softening plants are in successful operation since many people desire a water of zero hardness for household purposes.

Because of the versatility of the newer synthetic zeolites, many new and interesting applications are appearing yearly, not only in the field of water softening but also in the application of these materials to a wide variety of industrial processes, particularly the recovery of waste products where an exchange cycle may be employed. These may not be discussed here but those interested should consult some of the newer works on the subject.

In view of the steady increase in the number of municipal water softening plants, the comparatively low cost of individually owned home water softeners, and the rapid development of the industry supplying individually serviced softening units, it is quite evident that a larger and larger segment of the American population will enjoy the aesthetic and economic benefits accruing from the use of soft water as the years pass.

PART III. STABILIZATION

The increased emphasis which has been placed in recent years upon the stabilization of water supplies results from the realization on the part of superintendents of treatment plants that their responsibility for the quality of the treated water extends beyond the filters; that they must turn out a finished water that will neither incrust nor corrode the distribution system and that will reach the ultimate consumer essentially as it leaves the plant.

The basic processes of coagulation and softening which have been discussed in parts I and II of this series do not, as a rule, result in treated waters which will meet this criterion. Waters following coagulation may often be quite soft and the pH value so low that unless further treatment is provided excessive corrosion would result. On the other hand, water softened by the lime-soda process will also be soft, but will have a high pH value and will be more or less super-saturated with calcium carbonate.

It becomes of interest, therefore, to review the methods which have been developed to render waters non-incrusting, or non-corrosive as the case may be. Although such methods vary widely with respect to the theory involved, materials used and methods of application, they are usually collectively called "Stabilization."

Fundamental Nature of Corrosion

While there is still much to be learned about the fundamental nature of corrosion in spite of the very voluminous literature now available, the most commonly held conception is that it is an electro-chemical

Insoluble Calcium Carbonate Incrustation

(This deposit of calcium carbonate from an unstabilized lime-softened water reduced the pipe size from 10-in. to 5⅝-in. Recarbonation was adopted to prevent recurrence after the main was cleaned.)

process whereby a metal loses electrons and passes into solution in an area which thereby becomes anodic. The following equations have been employed to represent some of the reactions which take place:

1. $Fe = Fe^{++} + 2e$
2. $Fe + 2H^{+} = Fe^{++} + H_2$
3. $H_2 + 1/2\ O_2 = H_2O$
4. $1/2\ O_2 + H_2O + 2e = 2(OH)^{-}$

The first reaction shows iron entering solution with the loss of two electrons. The area within which the reaction takes place thereby becomes positive and acts as an anode.

The second reaction shows metallic iron reacting with hydrogen ions and passing into solution with the liberation of hydrogen gas which plates out on the metallic surface. If this hydrogen film could be maintained in place, protection against further corrosion would be afforded. Such a system is said to be polarized.

The third reaction shows how hydrogen may be oxidized by the dissolved oxygen present in the water.

The fourth reaction shows the mechanism whereby the two electrons lost in reaction (1) may be absorbed by dissolved oxygen and water molecules with the formation of negatively charged hydroxide ions. The dissolved oxygen in equation (3) is termed a de-polarizer and great emphasis has been placed for many years on the important part played by dissolved oxygen in corrosion since it is present to a greater or lesser degree in all aerated supplies. However, any oxidizing agent may, like oxygen, act as a de-polarizer and absorb the electrons, thus promoting corrosion. Among those which may be present in water supplies are free chlorine and nitrate ion. Many examples of extremely active corrosion under completely anaerobic conditions have been traced to one or the other of these agents.

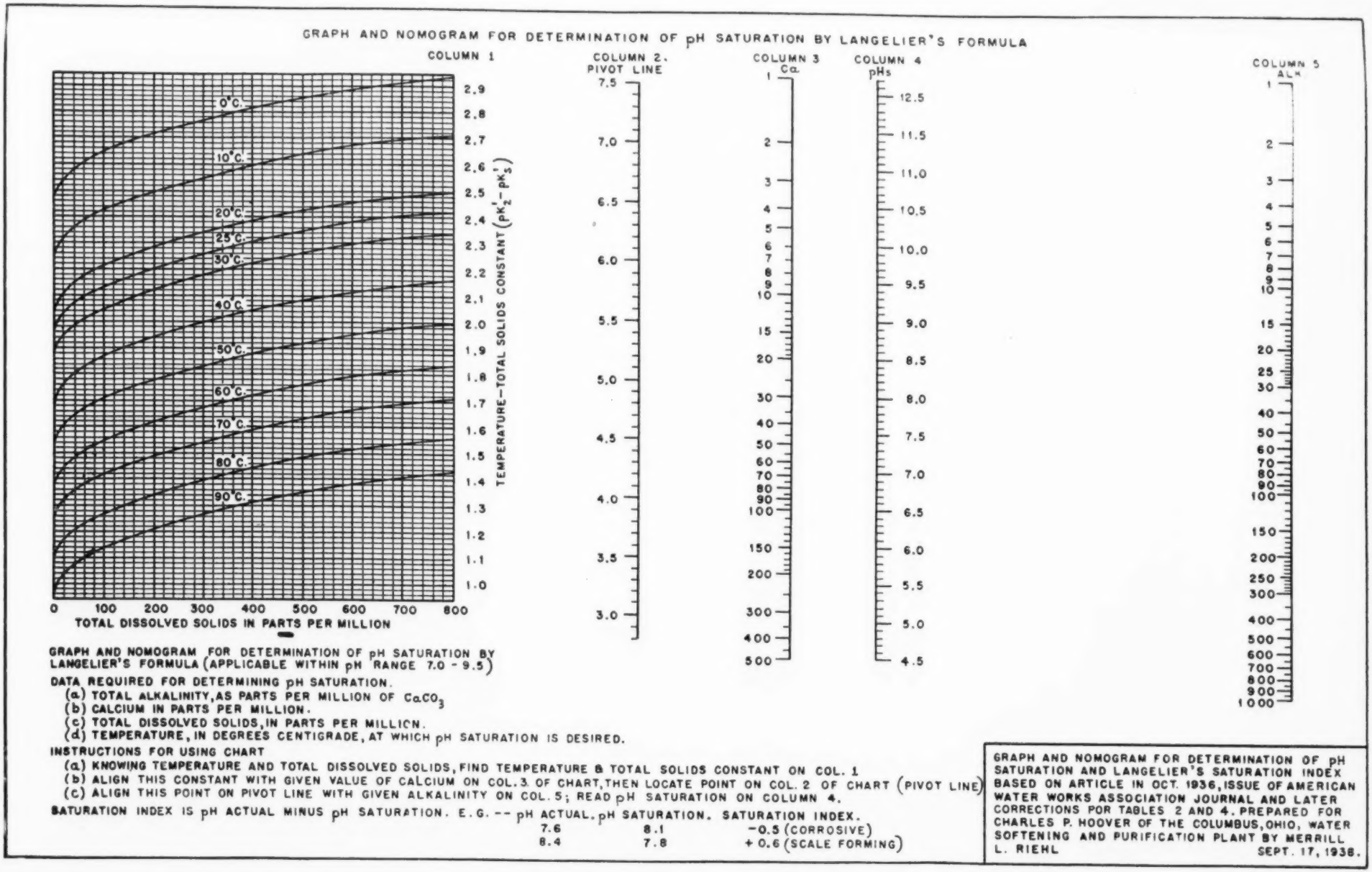
In the case of anaerobic corrosion, the iron which passes into solution by either reaction (1) or (2) above is oxidized and precipitated as ferric hydroxide, thus producing the tuberculation familiar to the water works man. In the case of anaerobic corrosion, however, no tubercules are formed, the iron remaining in solution, imparting a most unpleasant taste to the water and producing staining of fixtures by its oxidation when it comes in contact with air.

TABLE FOR CALCULATION OF ALKALINITIES

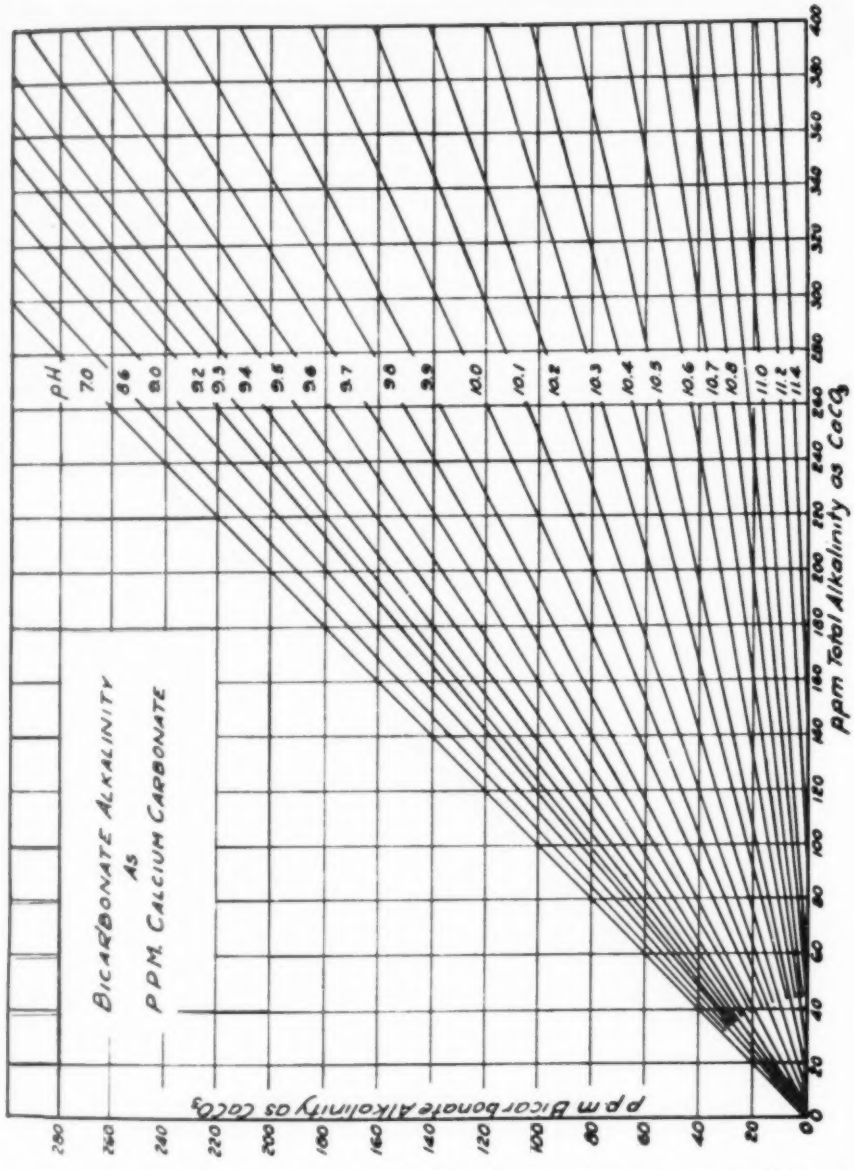
TITRATION	HYDROXIDE ION AS $CaCO_3$	CARBONATE ION AS $CaCO_3$	BICARBONATE ION AS $CaCO_3$
P = 0	0	0	T
P < M	0	2 P	M−P
P = M	0	T	0
P > M	P−M	2 M	0
M = 0	T	0	0

P = PHENOLPHTHALEIN TITRATION; T = TOTAL TITRATION; M = T−P.

Table for Calculation of Alkalinities


GRAPH AND NOMOGRAM FOR DETERMINATION OF pH SATURATION BY LANGELIER'S FORMULA
COLUMN 1
COLUMN 2. PIVOT LINE
COLUMN 3 Ca.
COLUMN 4 pHs
COLUMN 5 ALK
0°C.
10°C.
20°C.
25°C.
30°C.
40°C.
50°C.
60°C.
70°C.
80°C.
90°C.
TEMPERATURE—TOTAL SOLIDS CONSTANT $(pK'_2 - pK'_s)$
TOTAL DISSOLVED SOLIDS IN PARTS PER MILLION
GRAPH AND NOMOGRAM FOR DETERMINATION OF pH SATURATION BY LANGELIER'S FORMULA (APPLICABLE WITHIN pH RANGE 7.0 - 9.5)
DATA REQUIRED FOR DETERMINING pH SATURATION.
(a) TOTAL ALKALINITY, AS PARTS PER MILLION OF $CaCO_3$
(b) CALCIUM IN PARTS PER MILLION.
(c) TOTAL DISSOLVED SOLIDS, IN PARTS PER MILLION.
(d) TEMPERATURE, IN DEGREES CENTIGRADE, AT WHICH pH SATURATION IS DESIRED.
INSTRUCTIONS FOR USING CHART
(a) KNOWING TEMPERATURE AND TOTAL DISSOLVED SOLIDS, FIND TEMPERATURE & TOTAL SOLIDS CONSTANT ON COL. 1
(b) ALIGN THIS CONSTANT WITH GIVEN VALUE OF CALCIUM ON COL. 3. OF CHART, THEN LOCATE POINT ON COL. 2 OF CHART (PIVOT LINE)
(c) ALIGN THIS POINT ON PIVOT LINE WITH GIVEN ALKALINITY ON COL. 5; READ pH SATURATION ON COLUMN 4.
SATURATION INDEX IS pH ACTUAL MINUS pH SATURATION. E.G. -- pH ACTUAL. pH SATURATION. SATURATION INDEX.
7.6 8.1 −0.5 (CORROSIVE)
8.4 7.8 + 0.6 (SCALE FORMING)
GRAPH AND NOMOGRAM FOR DETERMINATION OF pH SATURATION AND LANGELIER'S SATURATION INDEX BASED ON ARTICLE IN OCT. 1936, ISSUE OF AMERICAN WATER WORKS ASSOCIATION JOURNAL AND LATER CORRECTIONS POR TABLES 2 AND 4. PREPARED FOR CHARLES P. HOOVER OF THE COLUMBUS, OHIO, WATER SOFTENING AND PURIFICATION PLANT BY MERRILL L. RIEHL
SEPT. 17, 1938.

Graph and Nomogram for Determination of pH Saturation by Langelier's Formula[1]



Graph for Determining Bicarbonate Alkalinity Where pH and Total Alkalinity Are Known (After Moore[6])

(Relations between pH, carbon dioxide, normal carbonate and hydroxide, and total alkalinity are given in original paper[6].)

Basis of Corrosion Control

A consideration of reactions (1) and (2) given above, immediately indicates two general methods which may be used to protect against corrosion. The first of these is to provide a protective coating so that the water does not come in direct contact with the metallic surface. These coatings are of two types, those mechanically applied and those formed upon contact with the water. Mechanically applied coatings include cement lining, applied either when the pipe is manufactured or in place after cleaning, bituminous coatings, likewise applied during manufacture or in place after cleaning, or a combination of the two. Coatings formed upon contact with water include phosphate coatings, silicate coatings, and calcium carbonate coatings.

Phosphate coatings are formed in place by feeding a nominal dosage of one of the several available molecularly dehydrated phosphates (sometimes called glassy phosphates). The dosage to be employed depends upon several factors, the most important being the pH and the total hardness of the water, but in any case the protection afforded appears to depend upon the formation of a protective film on the surface of the metal.

Silicate films may be formed in a similar manner by adding sodium silicate, the dosage required being considerably higher than for the glassy phosphates. This method of corrosion prevention has not been as widely employed as has the use of the glassy phosphates. The method appears to work best in hot water systems.

The formation of a protective film of calcium carbonate brings us to the second general method for corrosion control, namely, elevation of the pH by the addition of an alkali. The alkalis used for this purpose include lime, soda ash, and caustic soda. If the water is sufficiently soft so that the additional hardness introduced by the addition of lime is not objectionable, then lime is always employed because of its lower cost. If, on the other hand, it is not desired to introduce additional hardness then soda ash or sodium carbonate may be used, the choice depending upon relative cost and buffer capacity of waters being treated.

Whichever is used, the result will be the precipitation of calcium carbonate on the surface of the pipe at a definite pH value, this value varying with each individual water and depending upon a number of factors which are to be discussed later. If the pH value is raised too far above the critical value, then the coating formed will become so thick as to decrease the carrying capacity of the pipe, but if the amount of alkali added is insufficient to reach this critical pH value, the water may retain some of its corrosive properties. The question which immediately confronts the water works operator, therefore, is, "what must be the pH value of my final effluent in order that it may neither be corrosive, nor incrusting?" To the chemist, this question becomes, "how may I determine the pH at which a given water is exactly in equilibrium with calcium carbonate?" Before answering the questions, we must digress for a moment to consider the stabilization of lime softened water.

Stabilization of Lime Softened Water

As has been stated, water softened with lime or lime and soda ash will have a hardness dependent upon the dosage of chemicals added and the solubility of the precipitated sludge in the water being softened. Since the first factor may be controlled by the operator, the second becomes the critical or limiting factor. The solubility of calcium carbonate in distilled water at ordinary temperatures is very small, only 12 parts per million.

Every operator of a softening plant is familiar with his inability to obtain a water of this final alkalinity. This is due to the phenomenon of super-saturation which may be defined as solubility in excess of the equilibrium value. It may be illustrated by a simple experiment. In a beaker is placed a handful of sodium thiosulphate crystals, about 50 ml of distilled water is added and the mixture raised almost to the boiling point. As the crystals all dissolve more are added until excess crystals remain. The hot solution is now filtered through a coarse filter paper into a flask which is stoppered and allowed to cool slowly in contact with the air. No precipitation of crystals will take place although the solubility of the salt is many times greater at room temperature than near the boiling point. If now, one removes the stopper and adds to the clear solution a few tiny crystals of the material, the mass will set to a solid within a matter of seconds and the flask may be inverted without loss of liquid content. This is an extreme example, but the results of a slight degree of supersaturation over a long period of time may be equally startling and costly.

In an accompanying photograph is shown a section of pipe through which has been passed unstabilized water softened by the lime soda process. These calcium carbonate coatings may attain a thickness of two to three inches and a weight of several hundred pounds per section of pipe. If such water is passed without stabilization through the filters, the filter medium will be incrusted in a like manner and the size of the grains of sand or coal will increase to the point where the filter becomes relatively ineffective and cementing and solidification may take place.

Two general methods of stabilization of such water have been developed. The first consists in the use of the same molecularly dehydrated phosphates which are employed for corrosion control. Indeed, these materials were first developed and advanced for the prevention of the precipitation of calcium carbonate and their use as agents to prevent corrosion was a later development. The exact mechanism by which this remarkable effect is produced is not clear, but that they are extremely effective has been

well established. Furthermore, the dosage required to prevent the precipitation of calcium carbonate is usually substantially less than that required to prevent corrosion.

The second method of stabilizing water softened with lime or lime-soda has been used for many years and is termed "Recarbonation." This process consists in passing carbon dioxide gas through the softened water to convert a part of the calcium carbonate to the more soluble calcium bicarbonate, thus preventing its precipitation on the filter medium or in the mains.

We now find ourselves back to the same sixty-four dollar question which we faced in our discussion of corrosion control, namely, "what should be the pH of the stabilized water so that it will neither be incrusting nor corrosive?" The answer to this question has been the subject of constant study on the part of water chemists since about 1912, and the last fifteen years have witnessed a number of important and fundamental papers. It is our purpose here to briefly review some of these papers, summarize the specific contributions made by each, and indicate how the information presented may be used by the water works operator or chemist. References are given only to papers which have appeared in publications of the waterworks profession, where they may be consulted as desired.

Some Early Approaches

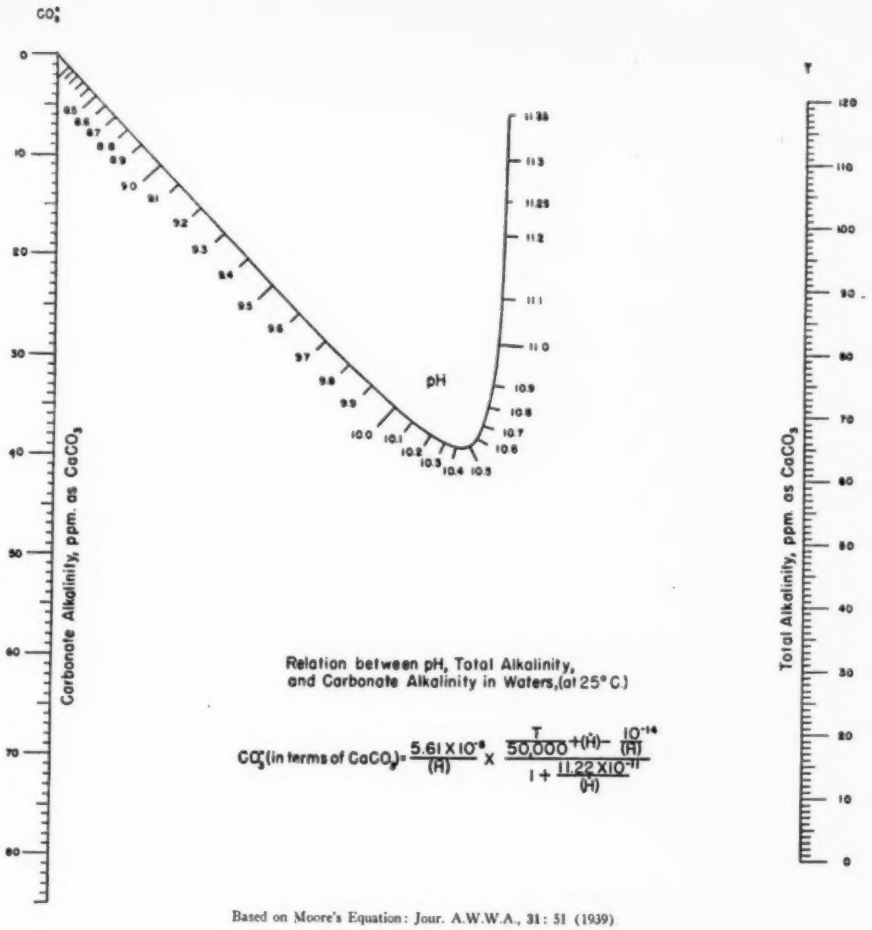
In 1912 Tillmans and his co-workers began a series of studies which extended over a period of twenty years and during which they developed the well known "Marble Test" for measuring stability. This test still remains the best laboratory method for controlling stabilization. It is the basis of the Enslow Continuous Stability Indicator which is now widely used. An even more elaborate modification of the same test is used by Hartung of the St. Louis County Water Co., and has been described by him[1].

The principle of the test itself is quite simple. The water in question is held in contact with calcium carbonate for a considerable length of time and the alkalinity determined before and after contact. If there is a decrease in alkalinity the water is supersaturated and incrustation would be the result of its use without further treatment. If there is an increase in alkalinity, the water has the property to dissolve a protective calcium carbonate coating and corrosion might result. If there is no change in alkalinity, the water is considered to be stable.

It is highly desirable, however, to have available a means of calculating this so-called "pH of saturation." Bayliss about 1930[2] published a curve showing the solubility of calcium carbonate in water of varying alkalinities and varying pH values. This curve was widely used by plant operators for several years. Its limitations, however, soon became evident. In our discussion of coagulation in Part I, we learned that every ion present in the water has some effect on the process. Similarly, physico-chemical studies have revealed the fact that the solubility of a salt is affected by every other ion present in the solution. Methods have been developed to calculate the so-called "ionic strength" of a water and by its use to correct the solubility of calcium carbonate for the presence of other ions present in the water.

Determination of the Forms of Alkalinity

When we speak of the forms of alkalinity in a given water, what do we mean? There are two entirely different answers to that question, depending upon the use to which the answer is to be put. The operator controlling his dosages of lime and soda ash in a softening plant wishes to know if he is correctly dosing his water. For that purpose, he uses the well-known differential titration with 0.02 N sulfuric acid employing both phenolphthalein and methyl orange as indicators, and then he calculates hydroxide, normal carbonate and bicarbonate ions in terms of calcium carbonate by the use of the table given in *Standard Methods*[3] or by the simplified table presented herewith.


Carbonate Alkalinity, ppm. as CaCO3
pH
Total Alkalinity, ppm. as CaCO3
Relation between pH, Total Alkalinity,
and Carbonate Alkalinity in Waters,(at 25° C.)
CO3 (in terms of CaCO3) = 5.61 X 10^-6 / (H) X T / (50,000 + (H) - 10^-14/(H)) / (1 + 11.22 X 10^-11 / (H))

Based on Moore's Equation: Jour. A.W.W.A., 31: 51 (1939)
Chart 2

Dye Nomograph Showing Relation Between pH, Total Alkalinity and Carbonate Alkalinity[5]
(Relations between total alkalinity and pH, carbon dioxide and bicarbonate are given in the original paper[5]*.)*

To use this nomogram, locate the value of total alkalinity on the right hand square and the pH of the water on the curved middle line. Lay a straight edge across these two values and the carbonate alkalinity, in ppm. as $CaCO_3$ may be read on the left hand square.

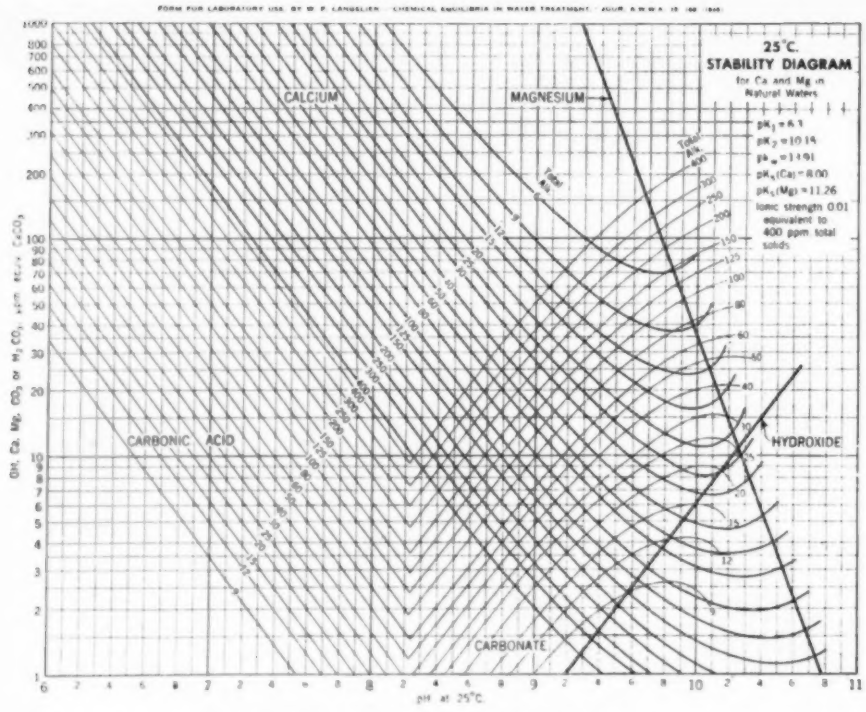
If for example, as pointed out by Dye, he prepares a solution containing 42.4 mg. of pure sodium carbonate in one liter of distilled water and titrates the 100 ml. sample with 0.02 N sulfuric acid using phenolphthalein and methyl orange as indicators, he will obtain a "P" titration of 2.0 ml., a "T" titration of 4.0 ml., and a "M" titration (by difference) of 2.0 ml. Using the table, he will calculate all of the alkalinity as normal carbonate, which is exactly what he added. Had the "P" titration exceeded the "M" titration, calculated as above, the sodium carbonate would have contained some sodium hydroxide and had his "P" titration been less than his "M" titration, his sodium carbonate would have contained some sodium bicarbonate. Under no circumstances, however, will his titration indicate the simultaneous presence of hydroxide, normal carbonate, and bicarbonate.

When the pH of the solution is determined, however, it is found to be 10.3 and a simple calculation indicates that the actual hydroxide ion concentration present in solution at that pH value, expressed in terms of calcium carbonate, is 10.0 parts per million. This hydroxide ion could only have resulted from the hydrolysis of the carbonate ion by the following equation:

$$CO_3^{=} + H_2O = HCO_3^{-} + OH^{-}$$

Since the equation indicates that for each hydroxide ion formed a bicarbonate ion is likewise formed, the alkalinity actually present in the solution is in three forms, 10.0 ppm. as hydroxide, 20.0 ppm. as normal carbonate and 10.0 ppm. as bicarbonate, an answer which it is impossible to obtain by the method of titration.

We arrive then at the conclusion that whereas determination of alkalinity by titration is and will continue to be a most useful tool for determining chemical dosages, it cannot and should not be used to determine the forms of alkalinity present in a finished water when stabilization is the end to be obtained. For this purpose, one of the new approaches must be used. In 1933, McKinney advanced a method for calculating the forms of alkalinity in terms of pH and free and combined carbon dioxide. His method also required a complete mineral analysis of the water. In 1936, Langelier[4] advanced a new method for calculating concentrations of bicarbonate and normal carbonate ions, and a method of calculating what he termed the "saturation pH" or pH_s. His method assumed the fol-



Stability Diagram—After Langelier[11]

This diagram may be used without salinity correction for natural waters from about 200 to 1000 ppm. of total solids. It furnishes a direct reading of pH_s which is applicable without correction at higher pH levels. It also gives the corresponding value of pH_s for magnesium.

lowing basic reaction for the reversible coating of a pipe with calcium carbonate:

$$CaCO_3 + H^+ \rightleftharpoons Ca^{++} + HCO_3^-$$

In the presence of the calcium carbonate film, its concentration may be considered to be a constant and the following equation results from the application of the mass law:

$$\frac{[Ca^{++}]\ [HCO_3^-]}{[H^+]} = K$$

Rearranging the terms and expressing each as a negative logarithm, we obtain:

$$pH_s = pCa + pHCO_3 - pK$$

If the pH of the water is less than about 9.0 he shows that $pHCO_3$ will be approximately equal to pAlk. He further demonstrates that pK is equal to the difference between two known constants, pK_2 the second dissociation constant of carbonic acid and pK_s the solubility product constant for calcium carbonate. The equation then becomes:

$$pHs = (pK_2 - pKs) + pCa + pAlk.$$

He further defines Saturation Index as pH—pH_s.

At the suggestion of Charles P. Hoover, Riehl[18] prepared and published a nomogram for the rapid and convenient determination of pH saturation using the Langelier equation. (See the accompanying Graph and Nomogram for Determination of pH Saturation by Langelier Formula.) Langelier suggested that similar equations might be derived for calculating free carbon dioxide and hydroxide ion and these equations were included in DeMartini's paper[16]. The basic objection to the use of both sets of equations lies in the fact that all concentrations are expressed either in equivalents or mols per liter. Moore[17] re-calculated these equations in such a form that the ionic concentrations are given in terms of parts per million as calcium carbonate. His equations are those which appear in the 9th Ed. of *Standard Methods*.[13] They may be more conveniently employed, however, by use of the curves which he presents in his paper.

One of his curves, to be used in determining that portion of total alkalinity present as bicarbonate, is shown herewith.

Dye[15] prepared and published nomographs which greatly simplified the determination of the forms of alkalinity. They are likewise based on Moore's equations and give ionic concentrations in terms of parts per million calcium carbonate. One of Dye's nomograms, to be used in determining that portion of the total alkalinity present as normal carbonate, is shown herewith. Larson and Buswell[19] reviewed Langelier's paper and suggest slightly different values for two of the constants used by him. Ryznar[10] reviewed Langelier's work and suggested that the saturation index is not always a true measure of the behavior of a given water and that a better measure is to be obtained by calculating its "stability index" which he defines as $2pH_s$—pH, the pH_s referring to that obtained by the use of the Langelier equation. Ryznar presents a table in which the behavior of some thirty-six waters are reviewed and shows that waters with identical pH_s values have stability indexes which may be quite different. He concludes that water having a stability index of less than 6 may usually be expected to form a calcium carbonate coating whereas the corrosive property of the water may be expected to increase as the stability index exceeds 7. Langelier's[21] most recent paper refines his equations and includes a consideration of equilibria as they pertain to magnesium hydroxide.

Langelier's stability diagram for calcium and magnesium in natural waters at 25° C. is presented herewith.

Simplest Approach

Confronted with all of the papers, charts, and nomographs which have been briefly mentioned above and examples of some of which are presented, what is the simplest approach for the average water works operator in order to determine the forms of alkalinity in a given water, and the pH at which his water should be maintained in order that it shall neither be corrosive nor incrust his distribution system?

Careful inspection of the equations of either Langelier or Moore indicates that their solution is both complicated and time-consuming. It is evident, therefore, that the use of the charts and nomographs is to be preferred. An inspection of Moore's charts, one of which is shown herewith, indicates that for fairly high values of alkalinity their use will yield accurate values for the ions desired. For waters of low alkalinity, however, the numerous curves on the chart converge so closely that it is almost impossible to make accurate readings.

The Dye nomographs, on the other hand, are perhaps even easier to use, but, like the Moore curves, it is difficult to read accurate values when the alkalinity is less than 30 parts per million. For waters having alkalinities of 30 or below, it is therefore best to calculate values for the different forms by use of the Moore equations if accurate results are desired.

Without question, the simplest method of determining the pH of saturation of a given water is by use of the Riehl nomograph of the Langelier equation, which is shown herewith. It should be clearly understood, however, that the value so obtained is not necessarily the exact value to be maintained but a reasonably close approximation thereof. The pH of saturation is to be regarded as an approximate measure of a directional tendency and in actual use it should be supplemented by frequent observations both in the laboratory and in the field.

In view of the data presented by Ryznar, it would seem well also for the operator to compare the pH_s of Langelier and the stability index of Ryznar in order to ascertain which of the two is the more reliable guide to the behavior of his particular water. As mentioned earlier in this paper, the Marble Test, or some variation thereof, carefully made on water with several hours of contact time allowed before titration, represents a most valuable method of laboratory control. When, in addition, frequent observations are made of the condition of the distribution system at convenient locations provided for this purpose, the operator may know that he is delivering to his consumers water of the highest possible quality.

PART IV—DETERMINATION OF pH VALUES

The development between the years 1882-87 by the great chemist Arrhenius of the theory of ionization was a revolutionary step forward in the history of chemistry. It provided for the first time concepts which made it possible to understand relationships which had previously been obscure. By means of the theory it was possible for the first time to understand the true nature of the acidity of solutions and the differences between strong and weak acids. Pasteur made numerous references to the importance of acidity in biochemistry and in the growth of micro-organisms.

Progress, however, was comparatively slow and up to the year 1910 a total of only about 350 papers had been published in the field. The first two decades of the twentieth century witnessed the publication by Sorensen in 1909 of his basic concept of pH, followed in 1917 by the classic paper of Clark and Lubs on "The Col-

orimetric Determination of Hydrogen Ion and its Applications to Bacteriology". In 1920 Clark published the first edition of his monumental work "The Determination of Hydrogen Ions", and this new field of chemistry had come of age.

In the decade 1920-30 colorimetric methods were refined and the hydrogen and quinhydrone electrodes applied to a great variety of problems. The glass electrode which was to become the most reliable and the most useful of all the tools of the chemist for this important determination, was developed in crude form in 1906-09. In 1924 two papers were published describing its application to the determination of pH value and by 1928 thermionic amplifiers had replaced highly sensitive galvanometers and electrometers and the first modern vacuum tube sets appeared. The present day vacuum tube potentiometer represents the greatest advance ever made in the determination of pH values. It is simple and, with proper care, almost fool-proof in operation, and it is applicable under a wide variety of conditions. The relatively high cost of these pH meters, however, means that they are not yet available in many of our water and sewage works laboratories throughout the country and colorimetric methods for the determination of pH values, because of the low first cost involved, are still very widely used.

The simplicity of the determination of pH by the use of indicators is such that the operator unfamiliar with the theory involved may unknowingly make serious errors in his determination. It is the purpose of this paper to point out some of these errors and to indicate how they may be avoided.

What is Meant by Hydrogen Ion Concentration or pH?

The hydrogen ion concentration or pH value of a solution may be defined as its "momentary" acidity or "intensity" of acidity as contrasted with its total or "titratable" acidity. For example, equal volumes of 0.1 M hydrochloric acid and acetic acid have the same total or titratable acidity as measured by the amount of alkali used for neutralization, but their momentary acidities or pH values are very different. Reference has already been made to the introduction by Sorensen in 1909 of the very convenient term pH to express this important quantity. He defined pH as a negative logarithm of the hydrogen ion concentration, or

$$pH = \log \frac{1}{[H^+]} = -\log [H^+] \qquad \text{Eq. 1}$$

Every operator is familiar with the fact that on this pH scale, neutrality is expressed as pH 7.00 and acidity increases with decreasing pH values and decreases with increasing pH values.

What are Indicators?

Almost from the beginning the color change of indicators has proved a useful and fairly accurate method of determining pH values. Indicators may be defined as those substances, usually weak organic acids or bases, which undergo a color change within certain pH ranges. It was originally believed that this color change was due to the ionization of the indicator into ions which possessed a different color from the parent molecule. For example

$$\underset{\text{Molecule}}{HI} = H^+ + \underset{\text{ion}}{I^-} \qquad \text{Eq. 2}$$

It is now known that in addition to ionization, a change in molecular structure takes place, but it is still customary to express one colored form in the indicator as (HI_a) and the other form as the indicator ion (I^-). Every operator is familiar with the fact that a color change of an indicator is not sharp but takes place gradually over a considerable range of pH value. One cannot fail to notice also that the useful pH range of color change or "virage" is essentially the same for all indicators, namely 1.6 pH units. The reason for this uniformity is not due to any property of the indicators themselves but to the sensitivity of the average human eye. The ionization constant of an indicator as an acid is calculated as follows:

$$\frac{[H]^+ + [I^-]}{[HI]} = Ki \qquad \text{Eq. 3}$$

which can be rearranged to yield the following expression:

$$pH = pK_1 + \log \frac{[I^-]}{[HI]} \qquad \text{Eq. 4}$$

From this expression it is noted that the pH is proportional to the logarithm of the ratio of the two colored forms. If the human eye were able to discern ten percent of one color in the presence of ninety percent of another color, solving this expression indicates that indicators would have a useful pH range of 2 pH units and the range would be given by the expression:

$$\text{pH range} = pK_1 \pm 1 \text{ pH unit} \qquad \text{Eq. 5}$$

Thus an indicator with the pK_1 of 4 would have a useful pH range of pH 3.0 to pH 5.0. Experience indicates, however, that the average human eye is able to discern only about fourteen percent of one colored form in the presence of eighty-six percent of another, and solving the expression for these values gives a useful pH range of 1.6 pH units as stated above.

The usual technic involving either a block or a slide comparator or some modification thereof, consists in adding five percent by volume of the indicator to the water sample, mixing and comparing the tube with a set of buffer color standards. Two types of errors may be made and they will be discussed separately.

The first type of error is that due to the effect of the indicator itself on the solution to be tested. As an extreme case, let us assume that we are to determine the pH value of pure carbon dioxide-free distilled water using bromthymol blue indicator whose useful pH range is 6.0 — 7.6. If an indicator solution whose pH is 6.2 is used, one reads a value of pH 6.25 for the sample of water. If the indicator solution has a pH of 7.60 one reads a pH value of 7.55 for the sample of water. In other words, instead of determining the pH of the sample of water, all we determined was the pH of the indicator solution. That the same type of error may be made in determining the pH of certain waters is shown by the second example where the water tested has an alkalinity of 62 ppm. and contains no free carbon dioxide.

Tested with a wide range indicator whose pH is 4.3 a value for the water of pH 7.3 is obtained. If the indicator pH is 7.2 the pH of the water is found to be 7.8. If the pH of the indicator is 10.3 the pH of the water is found to be 8.4. This is admittedly an extreme case since the wide range indicator has been used over a very wide range of pH values. However, with the usual indicators and waters of very low alkalinities such as are encountered in a large number of water treatment plants, errors almost as large may be encountered. It will be interesting to examine the reason for these errors and to see how they may be avoided.

Buffer Capacity. What is it?

The buffer capacity of a solution may be defined as a measure of its resistance to a change of pH value when acid or alkali is added to it. Well buffered solutions are usually composed of a mixture of free acid and its salt or free base and its salt as is known by every chemist who has determined the alkalinity of water using 0.02N sulfuric acid. During the greater part of the titration where a mixture of acid and salt are present in the titration vessel, no indicator change takes place and the solution is buffered. It is only at the end of the titration when all free acid has been neutralized that the indicator changes color. The buffer capacity of a given solution depends not only upon the total concentration of acid and salt present, but also upon the ratio of acid to salt. The hydrogen ion concentration of an acid-salt mixture is given by the expression:

$$(H)^+ = Ka \frac{(Acid)}{(Salt)} \qquad \text{Eq. 6}$$

$$pH = pK + Log \frac{(Acid)}{(Salt)} \qquad \text{Eq. 7}$$

It exerts maximum buffer capacity or resistance to change of pH value when the concentrations of acid and salt are equal. The buffer capacity of natural and treated waters is exerted almost entirely by the forms of alkalinity present. In raw waters, for example, the buffer system will consist of free carbon dioxide and bicarbonate ion. In treated waters, the system may be bicarbonate ion and carbonate ion. The hydroxide ion may also be present. Evidently, therefore, waters of high alkalinity would be expected to possess proportionately high buffer capacity whereas waters of very low alkalinity will have little buffer capacity.

For example, when the same wide range indicator used above was employed to determine the pH of a raw water having an alkalinity of 284 ppm. and containing 38 ppm. of free carbon dioxide, determinations with three bottles of wide range indicator having pH values of 4.3, 7.2 and 10.3, yielded a uniform value of 6.90 for the pH of the water. The operator determining the pH value of a soft surface water following coagulation and whose alkalinity may not be more than 5—10 ppm. may easily make an error of several tenths of a pH unit in determining its pH value unless very careful precautions are observed.

Equation 7 above also explains a very interesting property of buffered solutions, namely, that they may be rather largely diluted without appreciable change in pH value. In this respect they differ markedly from unbuffered solutions. For example, if one adds to one volume of .1 N hydrochloric acid, pH = 1.0, nine volumes of distilled water the resulting solution will be .01 N and its pH will be 2.0. A second tenfold dilution will yield a solution with a pH of 3.0.

On the other hand, if one dilutes a well buffered natural water with an equal volume of distilled water, the pH of the mixture will differ only slightly from that of the undiluted water. If a sample of such water is diluted ten times with distilled water, its pH will be found to have been increased by less than 0.2 pH unit. Equation 7 shows that the pH of a buffered solution is a function of the *ratio* of acid

to salt and obviously such a ratio would not be changed by dilution. Later in the paper the slight change which does take place will be explained.

Isohydric Indicators

Ideally, the pH of the indicator used for a determination should be the same as the pH of the water to be tested. Such indicators are called "Isohydric". Such indicators, however, are difficult to prepare and even more difficult to keep since they readily change their pH value upon standing. In the ideal case and using thymol blue pH 8.0-9.6 as an example, one would have available five different bottles of indicator solution adjusted to pH values 8.2, 8.5, 8.8, 9.1, 9.4. The first determination would be made with the mid-point indicator and a second determination then made using the bottle of indicator which corresponds most nearly to the value obtained in the first test. By the use of such technic, very accurate results can be obtained by the colorimetric method on unbuffered solutions.

A second but more tedious method consists in determining the pH of the sample using a small volume of indicator and repeating the determination with a larger volume of indicator. If no change in pH is observed the result may be considered to be correct. If a change upward or downward is observed when the second determination is made, the pH of the indicator solution itself is adjusted by the careful addition of small quantities of 0.01 N acid or alkali until the same pH value is obtained for the water using two different volumes of the indicator. One is thus assured that the indicator has been adjusted to a pH very close to that of the water tested.

A compromise most commonly used is to employ indicators adjusted to the mid-point of their useful pH range. While indicator solutions are adjusted to this point before being shipped they change rapidly upon standing. They should be frequently adjusted by the careful addition of acid or alkali to the mid-point. In the case of the thymol blue mentioned above, this may be done after shaking to observe the color of the foam produced. If the indicator is too acid, the foam will be bright yellow with a tinge of pink. If it is too alkaline, the foam will be a deep bluish purple. At its mid-point, the foam produced by shaking is a gray-green which is easily recognized.

Probably the most difficult type of water for accurate pH determination by the colorimetric method is the effluent from a coagulation plant before stabilization. Such a water will usually have very low alkalinity and may contain relatively high concentrations of free carbon dioxide. The preferred technic for such determination is as follows: The indicator to be used is added to the empty colorimeter tube, the sample drawn from the container into a 10 ml. pipette, the tip of the pipette placed in the indicator solution and the water allowed to flow into the tube. If the pipette is slowly raised, as the water passes into the tube a uniform mixture of water and indicator may be secured without further mixing.

The pH is then read quickly before loss of carbon dioxide takes place. Such waters should never be filtered before the pH is determined, since filtration will provide sufficient aeration for substantial loss of carbon dioxide and consequent change in pH value. Reference to Equation 7 will illustrate why this is so. In that equation "salt" is represented by alkalinity and if the alkalinity of the coagulated water is very low we have a fraction with a very small denominator and obviously a small change in "acid" which in this case is free carbon dioxide, will produce a relatively large change in pH value.

Errors Due to Salt Effect

In recent years our knowledge of the behavior of ions in dilute aqueous solutions has been greatly expanded and new concepts have been advanced which have served to change in some respects our older ideas. The theory of ionization as originally advanced by Arrhenius did not take into consideration the effects exerted by the different ions present in solutions. All of us are familiar with the fact that if a sample of gas at ordinary temperature and pressure is compressed its volume will decrease inversely with the pressure until a point is reached where the volume of the particles themselves and their mutual attraction causes the law to fail. The ions in a dilute solution may be compared to the particles of gas except that the ions are electrically charged and their effects upon each other cannot be ignored even in dilute solutions.

For example, let us suppose that we determine colorimetrically the pH value of a sample of potable water and a sample of sea water and find identical values of pH 8.20. The hydrogen ion *activities* of the two solutions are not, however, the same. The sample of potable water had an "ionic strength" much less than the buffer color standard with which it was compared and the value which we read was too low by about 0.18 pH unit.

On the other hand, the ionic strength of the sea water was more than ten times greater than that of the buffer color standard and the value which we read was too high and must be corrected by approximately the same amount. This is due to the fact that the color of an indicator is determined by the ratio of the *concentrations* of its two colored forms and not of their activities. When one determines what we usually term the pH of a sample electrometrically, what we actually determine is the hydrogen ion *activity* which should be expressed as paH.

The difference between the pH value of a solution determined colorimetrically and its paH value determined electrometrically, is called the "salt effect" of the indicator. If the ionic strength of a given solution is the same as the ionic strength of the buffer color standard with which it is compared, then identical values will be obtained using colorimetric and electrometric methods. In the case of natural and treated water, however, their concentrations expressed in moles per liter will vary from perhaps 0.001 M to 0.01 M and their ionic strength while differing from the above values, are proportionately small whereas the ionic strength of the buffer color standards now available vary from 0.05 M to 0.1 M which means that the water or sewage works operator may expect to obtain for a given sample a colorimetric pH value approximately 0.2 pH unit lower than the value he would obtain had he used a pH meter.

Inasmuch as the same term pH is used throughout most of the literature to express both values, the situation is definitely confusing. It would be greatly simplified if values determined with the pH meter were expressed as paH and values obtained colorimetrically were expressed as pH. Any value could then be expressed in terms of the other by adding or subtracting the appropriate salt correction. This difference may not be important in some cases but it may be quite important in others. In Part III of this article ("Stabilization"), the importance of the pH of the finished water was emphasized and its influence upon the corrosive or encrusting properties of a given water was discussed. In that paper the term pH was used throughout whereas most of the newer theories of stabilization which were discussed have been based upon calculation of the activities of the ions present in the treated water and the equations presented yield values for hydrogen ion activities and not hydrogen ion concentrations. Specifically, the "saturation pH", or pH's of Langelier, is in reality a paHs and if the operator is employing colorimetric methods for his determinations he should correct his values accordingly.

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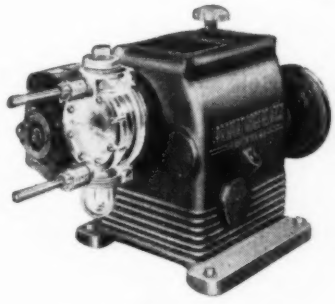


Fig. 1
Heavy Duty Chem-O-Feeder
0-8 gal./hr.
0-100 lbs./sq. in.

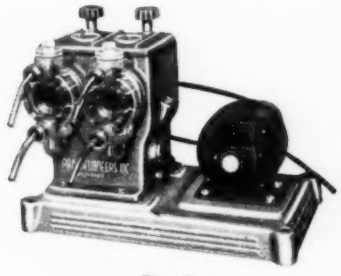


Fig. 2
Duplex Chem-O-Feeder
0-16 gal./hr.
0-100 lbs./sq. in.

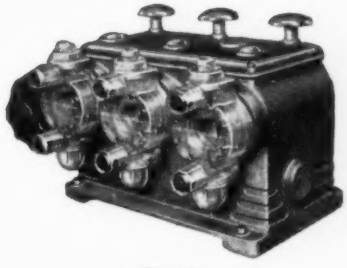


Fig. 3
Triplex Chem-O-Feeder
0-24 gal./hr.
0-100 lbs./sq. in.

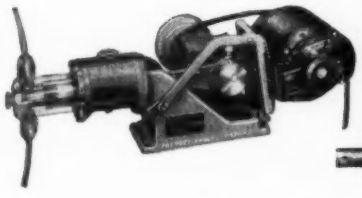


Fig. 4
High Pressure Midget
Chlor-O-Feeder
0-6 gal./hr.
30-200 lbs./sq. in.

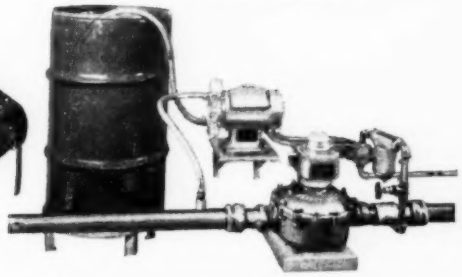


Fig. 5
Low Pressure Automatic and
Proportional Chem-O-Feeder
0-5 gal./hr.
4-100 lbs./sq. in.

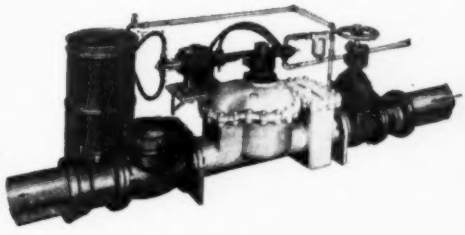
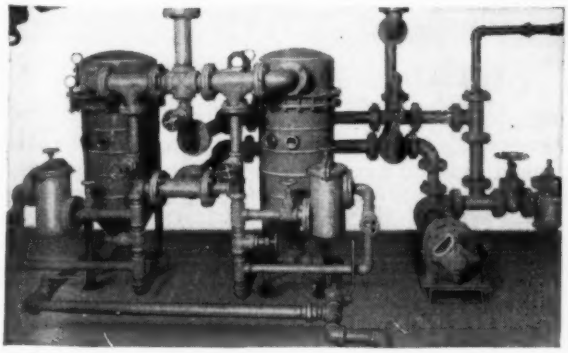


Fig. 6
High Pressure Automatic and
Proportional Chem-O-Feeder
0-5 gal./hr.
30-200 lbs./sq. in.



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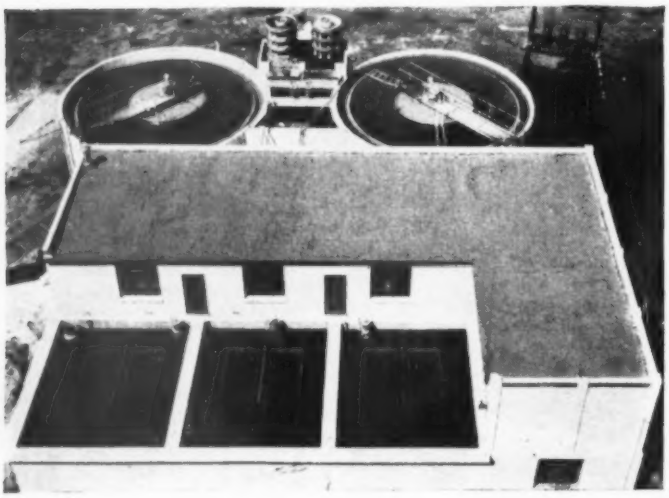
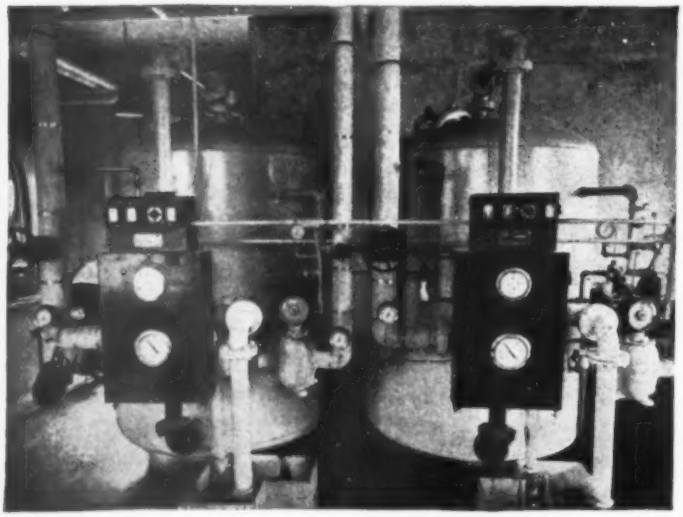


Accelator



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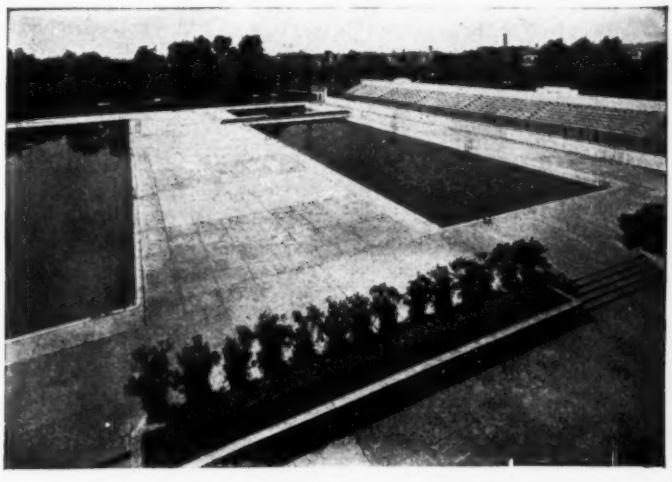

Group of pools protected by an Infilco Recirculating System.

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CONTROL OF METAL CORROSION*

By W. T. McCLENAHAN

Prin. Constr. Engr., Chicago San. Dist., Chicago

ALTHOUGH this paper discusses the control of metal corrosion in a sewage works, it has application to water plants as well, because moisture is a principal corrosive agent in both. This article will describe briefly the occurrence, the probable causes and the cures of metal corrosion or metal failure in the works of the Chicago Sanitary District.

It might be well, at the outset, to define the term sewage gas, to which frequent reference will be made hereafter. Sewage gas, as used in this paper, is the gas which arises from domestic or industrial sewage. It is not a definite compound but a heterogeneous mixture of gases, the most important of which—from the corrosion standpoint—are water vapor, hydrogen sulfide, carbon dioxide and ammonia. Oxygen is, of course, present from the atmosphere.

By mechanisms not fully understood, hydrogen sulfide, when absorbed into a condensate gathering upon cold surfaces, oxidizes to sulfurous and sulfuric acids, which are very corrosive to metal. The hydrogen sulfide itself, having a very small molecule, will penetrate most paint films to attack the metal and form sulfides. Such, in general, are the atmospheric conditions about a sewage works.

In the sewage itself can be found oils, greases, soaps and fatty acids. These emulsified materials tend to collect at the water line and, being solvents, act to soften most paints so that they are easily damaged by floating materials. Mineral oils and greases, however, protect metal from corrosion to some extent when they cover the surface.

Metals Affected

Unprotected structural steel in sewage plants is everywhere seriously attacked by moisture, especially in the presence of sewage gas. The steel must always be either galvanized or well painted, or both, to preserve its integrity. The Chicago Sanitary District makes a practice of painting galvanized surfaces after several months of weathering.

Cast iron is moderately attacked by moisture and sewage and sewage gas, but structurally it is not seriously affected by corrosion.

Copper, brass and bronze are all more or less attacked. Copper flashing, for instance, is of little value where sewage gas is strong since it becomes very brittle and readily breaks. Brass stems in small valves in the gas-collecting system of an Imhoff Tank at Downers Grove, Ill., eighteen years ago were all soon broken inside the bonnets where they were exposed to damp sewage gas. Silicon bronze, though attacked by the gas, is less subject to embrittlement than are other bronzes and brasses; it too discolors, with a loose brown powder spreading over the surface but without pitting. The discoloration does not seem to affect the strength of the metal greatly. Experience has shown that brass and bronze are quite satisfactory for the seats and stems of the valves handling sewage and sludge liquids. The corrosion damage occurs only when these metals are used in contact with sewage gas.

For various reasons, the district has avoided the use of aluminum in its plants. Several years ago aluminum sheet failed badly in louvers in a gas vent over a coarse screen chamber at one of the pumping stations where the sewage gas was very strong. The aluminum sheet developed pustules of corrosion all over the surface, which filled with a brownish white powder. A peculiar lamination of the metal occurred at the edges of these corrosion pits, and a sample of the louvers brought into the office continued to give off the odor of hydrogen sulfide for several weeks. It was suggested that this corrosion was entirely due to electrochemical action set up between the aluminum sheet and the bronze hinges which were unfortunately used in conjunction with the louvers. The author, however, doubted the accuracy of this explanation because the pustules appeared to be too uniformly distributed over the sheet. Electrochemical corrosion between the two metals would have tended to make the corrosion more intense in the vicinity of the bronze hinges.

Aluminum containers for air diffusers are reported to have failed at Cleveland, Ohio, and at Ann Arbor, Mich. Aluminum pipe failed in a digestion tank at Iowa City, Iowa, and aluminum Tow-Bro sludge collectors corroded in final settling tanks at Milwaukee, Wis. Whether this failure of aluminum is peculiar to sewage works the author is unable to say, as the cause has never, to his knowledge, been determined. The white powder observed was thought to be aluminum hydrate.

At normal temperatures, austenitic types of chrome steel are practically unattacked by sewage and sewage gas, except where the chloride ion is present because of the use of ferric chloride in acidifying sludge or for other reasons.

Non-austenitic high-chrome steel (28 per cent), however, failed miserably when incorporated into floats about 36 in. in diameter and 18 in. deep. The floats developed cracks near the weld lines, and some were punctured by a peculiar type of corrosion. Apparently the rolls in the sheet mill were not always clean. Consequently, small pieces of scale or slag were rolled into the sheet and were not discovered until the floats had been made and exposed to the sewage. These particles of scale, being electronegative to the metal, set up little galvanic cells until they ate themselves out of the sheet. When examined afterward the chrome sheet appeared moth-eaten, with the holes not uniformly distributed over the sheet nor in all sheets but in groups or patches on some of them. In places the holes extended clear through the metal, causing leakage and destruction of the floats.

For air ducts, electrical sheet-metal boxes and pipes carrying air, galvanized copper-bearing steel is preferred, except where cast iron is indicated. Recently, however, a number of galvanized copper-bearing steel pipes, installed vertically in a raw-sewage influent channel and delivering air to diffuser plates below, became badly pitted on the outside. This condition may possibly have been due to segregations in the metal affording areas of electropotential difference which, when aerated, developed local corrosion cells.

Where small cast-iron or steel pipe or fittings are to carry air to diffuser plates, it is advisable to galvanize the metal on the inside, because the volume of the zinc oxide formed by corrosion is much less than that of iron oxide or hydroxide which would be formed from the corrosion of bare iron or steel. Since these smaller pipes carry compressed air which is often chilled below the dew-point and since the air is frequently wet, corrosion is very active. At other times the air may be warm and dry, so that the previous corrosion products are dehydrated and blown along to clog the diffuser plates. Zinc coatings, however, are of no value in an aeration tank where they contact well-aerated sewage or activated sludge. The severity of the attack seems to increase from the inlet ends of these tanks to the outlet ends, suggesting the thought that it is due to a biologic change in the sewage. It is known that the carbon dioxide increases from one end of these tanks to the other, and Uhlig [1] states that carbon dioxide in solution accelerates the rate of corrosion of zinc. A galvanized coating on a test sample placed at the outlet end of one of the aeration tanks disappeared completely in 45 days.

Large air mains in the plants always carry warm, dry air direct from the compressors. Since no corrosion can occur at moderate temperatures without the presence of moisture, these mains do not corrode on the inside at any time and are therefore made of ordinary structural steel. Galvanizing is unnecessary and organic coatings—such as asphalt, coal tar and paint—are objectionable, as they all tend to dry out, polymerize and oxidize to a powder or flake, which will blow along into the diffuser plates. To prevent corrosion during construction, however, it is required that the inside surfaces of these large mains be temporarily coated with a paraffin compound, which is later removed with solvent just before the mains go into service.

Use of Paints

In the author's judgment, vinyl-resin and chlorinated-rubber paints, because of their imperviousness, are the most protective organic coatings thus far developed. However, because of the cost of preparing the surface for them—by sandblasting or by some other equally effective process—so that they will adhere to the steel, they are rarely economical in sewage plant maintenance.

For outside air exposure where conditions are not too damp, nothing has been found more economical than a paint made with linseed oil reinforced by phenolic varnish. The more the linseed oil is heat-treated, the more impervious and durable it becomes. The painters, however, object to the heavier bodies, so a compromise has been reached by specifying "M body." This amount of heat treatment lengthens the life of the oil, and at the same time the workability of the paint remains acceptable to the painters.

Since the humidity in many of the plant buildings is very high, considerable condensation occurs in the wintertime, particularly on the inner surfaces of outside doors and windows. As linseed oil tends to hydrolyze with moisture and lose its value as a protective film, inside paints for metal in all of the structures are made entirely of phenolic varnish vehicle. This type of vehicle not only resists moisture better than linseed oil, but it also affords

*Reprinted from the *J.A.W.W.A.*, Vol. 40, p. 606, (1948) by permission.

a harder finish for handrails and similar surfaces.

For underwater protection of steel, a system of painting has been developed which, if properly carried out, is very satisfactory. The steel surface is first thoroughly cleansed by brushing and scraping and is then treated with phosphoric acid. Next the surface is primed with a phenolic paint containing about 25 per cent by weight of the pigment, zinc chromate, which is able to passivate the steel so that it resists corrosion. To inhibit corrosion the zinc chromate must go into solution in the moisture which penetrates the film to the steel, but the strength of that solution must not be reduced by dilution below a certain minimum value or passivation of the steel will not result.

Moreover, a great volume of water passing over the surface in direct contact with the paint film tends to extract the soluble zinc chromate from the surface, so that the effective life of the paint is shortened by the loss of its inhibitive pigment. To prevent this dilution of the inhibitor next to the steel, and also its continued extraction by solution from the surface, it is best to cover the prime coat with a heavy film of bitumen having a dried thickness of 1/16 in. The bituminous coating used has generally been a fibrated asphalt emulsion, but a coal-tar coating is undoubtedly better if it can be applied without lifting the prime coat. Coal-tar emulsions are made which seem to be quite satisfactory. At the Calumet sewage works the tubs of the Oliver filters were treated in this way in 1935, using a fibrated asphalt emulsion as a top coat; it was not necessary to recoat the surfaces for about seven years, even though the tubs were exposed to sewage sludge acidified with ferric chloride to a pH of about 3.5 and were subject to abrasion from rocker agitators.

It has been discovered, however, that when the asphalt emulsion is used for this purpose it must be given an unusually long time to dry—about two weeks is desirable, but a month is better—before the surface is submerged, or the bitumen may re-emulsify.

It may be stated generally that coal-tar coatings are more impervious to moisture than asphalt coatings of the same thickness but are more subject to alligatoring in hot weather and cracking in cold weather. Hot bituminous coatings applied by dipping or spinning methods are better than those applied by daubing, which leaves many pinholes as sites for corrosion.

When well dried, water-emulsion coatings are, on the whole, more impervious than are so-called cutbacks, and they develop fewer pinholes for rust.

Preparation of Surface

A word should be said about the preparation of the metal surface for painting. The surface to be painted must be freed of all oil, grease, dirt, loose scale and rust, and loose paint. Rust pits and reentrant angles must be scraped clean, and old paint, where it is broken, must be scraped back to sound material.

Following this cleaning work, it is advantageous to wash the surface with phosphoric acid, which fortifies the metal against sulfates and carbonates as well as against oxidation. The acid also improves the bond of the paint to the steel. Chromic acid, in the author's estimation, is a detriment to the phosphoric acid wash. Certain phosphoric solutions produce better coatings than others, since some of them draw apart into little islands as they react with the steel. The coating should dry to a uniform color and a continuous film.

The next item of importance in preparing the surface is that the metal shall be absolutely dry when the paint is applied. Flame-cleaning is ideal for this purpose if it can be used safely, but it is not suitable in sewage works because of the explosive nature of sewage gas, which is almost always present in the very places where moisture on the surface is a problem.

If flame-cleaning cannot be used, the surface is washed with a solvent (mineral spirits, turpentine, alcohol and the like) and is then quickly wiped dry with a clean, dry rag and immediately painted. The solvent, having a higher affinity for the steel than has the moisture, displaces the latter, so that it can be wiped off in the drying operation.

Corrosion of Contiguous Metals

Twenty-five years ago the Chicago Sanitary District installed an 8-in. check valve in the discharge of a Nash hydroturbine air compressor. The Nash blower, it will be remembered, depends upon a water piston to do the compressing. As the air temperature rises during compression, its capacity for moisture increases. With this type of compressor, therefore, a certain amount of water must be fed in constantly to replenish that which evaporates. The compressed air, moreover, tends to entrain free moisture whenever the amount of water supplied is greater than the amount needed to make up for evaporation losses.

In order to reduce the back pressure on the blower due to friction, the clapper of this particular check valve was made of aluminum, while the hinge pin and valve seat were unfortunately made of bronze. Since the free moisture afforded an electrolyte, conditions were indeed perfect for electrochemical corrosion. The aluminum, being anodic to the bronze, went into solution and disappeared from the edge of the clapper, so that the bronze seat corroded nearly through the disc. Inside the hinge, where the dissolved aluminum could not get away, aluminum hydroxide precipitated in the joint until the pressure of the salt became so great that the aluminum part of the hinge cracked. This experience showed that such light clappers should be made of fiber or plastic which will neither corrode itself nor induce corrosion in the seat or hinge. Furthermore, the incident emphasized the well-known principle that when two metals are associated in damp locations they should always be electrically insulated from each other.

Corrosion of Noncontiguous Metals

Galvanic corrosion may also occur when the two metals are not in actual contact nor metallically connected in any way.

In dewatering sewage sludge with Oliver vacuum filters, the drums in the plants were originally covered with Monel wire mesh (No. 17 U.S. Ga. wire with five openings per inch) over which a heavy wool blanket was stretched tight for a filter medium. The blanket was then held in place by a silicon-bronze wire (No. 12 B.&S. Ga.) wound around the drum on a 1½-in. pitch. There was no metallic contact between the Monel mesh and the bronze wire, the two being everywhere separated by the wool blanket.

In operation, the drum rotated in a tub filled with sewage sludge acidified by ferric chloride to a pH of about 3.5. As the drum rotated, the water (and acid) was sucked out of the sludge cake (and the wool blanket) by a vacuum of 20-24 in. of mercury maintained in the upper compartments of the 24 sections of the drum circumference.

It was found that both the bronze wire and the Monel mesh corroded away, the bronze wire lasting about two months and the Monel mesh about two years. It was surmised that electrochemical corrosion was involved, but how and why the two metals produced electric current in this way could not be definitely explained, since they were nowhere in contact. Moreover, in a galvanic cell one metal is usually protected by the sacrifice of the other in producing the flow of current, yet both metals were lost.

A possible explanation is offered by Evans [2], who cites the fact that when a metal is submerged in an electrolyte and one spot is aerated while another remains in contact with quiescent liquid, a flow of current will occur between the two areas. In iron and other base metals, the aerated spot will become cathodic to the quiescent area. In copper and the noble metals, the aerated spot becomes anodic unless the aeration is very gentle, in which event it may become cathodic to the quiescent area. These conditions certainly existed on the drum surface. The metals in the lower portion were submerged in a quiescent liquid while they were aerated in the upper portion.

Other factors may also have entered into the phenomenon. For instance, what was the effect of the molecules of air impinging first upon the silicon-bronze wire and then upon the Monel wire, always in that order? Were electrical charges being carried across from one wire to the other and returning by way of the liquid in the submerged portion? The fact that the areas of the two metals were in the ratio of 1:18 while their corresponding lives seemed to be in a 1:12 ratio would seem to indicate that they were in some way being commonly affected.

To eliminate this corrosion the drums were redesigned. The Monel mesh was replaced by slotted wooden panels to furnish drainage beneath the blanket. The wood panels were laid on the surface of the drum to produce longitudinal grooves evenly spaced around its circumference. The blanket was then stretched over the drainage panels and held tight by wooden splines driven outside the blanket into these longitudinal grooves and nailed to the drum surface. With both metals eliminated by this construction, the corrosion problem ended.

Bolt Breakage

Where metal failure occurs the investigator must be wary of drawing hasty conclusions. Even though the evidence points to corrosion of some sort, he must remember that other agents of destruction are at times responsible.

In the construction of aeration tanks at Calumet, a very serious breakage of bronze stud bolts occurred in the bonnet flanges of 4-in. valves used in air lines feeding the diffuser plates. These valves were designed with their bonnet flanges set down so close to the valve body that it was necessary to use four stud bolts to fasten the flanges together. To expedite the servicing of the valves, the stud bolts were required to be of bronze. The valves

were installed early in the fall and remained in the open throughout one winter. In the spring it was found that over 400 of the bolts had been broken at the root of the thread, either just under the nut or just above the bottom flange into which they screwed. Examination of the broken surfaces of the bolts gave the impression of intergranular corrosion, but most crystallization and inter-granular failures are caused by frequent reversals of stress, to which these bolts were not subject. Moreover, corrosive conditions were quite mild in this location. It was finally concluded that the bolt breakage was due to excessive stress caused by the difference in the thermal expansion coefficients of the bronze bolts and the cast-iron flanges which the bolts gripped. Another factor involved was the nick effect of one or two exposed threads, which caused a concentration of stress at the narrowed sections.

To avoid further trouble, the stud bolts were changed to steel (whose thermal coefficient is close to that of cast iron) with bronze nuts for easy removal, and no failures have since been experienced. Silicon bronze has also been used successfully for such bolts because it is sufficiently ductile to adjust itself to the effects of temperature.

Cathodic Protection

Water works men will probably be interested in the means taken for protecting the inside surfaces of a 250,000-gal. elevated steel water tank at the West Side Sewage Treatment Works. This tank, which holds chlorinated aeration plant effluent for various plant uses not requiring pure water, is 40 ft. in diameter and 150 ft. high to the top. It has an elliptical bottom, a conical steel roof and a 4-ft. riser pipe in the center which houses three 8-in. cast-iron pipes, one used as an overflow and the others for filling and drawing purposes.

Recently, to save the cost and trouble of frequent shutdowns for interior painting, a contract was awarded for the cathodic protection of the tank bowl and riser below the water line and for a special paint job inside the tank above the water line, including the underside of the roof where the cathodic protection does not reach.

Since ice was known to form in this tank and do damage to any construction inside it, the anodes could not be left hanging from the roof through the winter. If platinum or long-lasting magnesium anodes were to be installed, they must be removed from the water, stored through the winter and then replaced in the spring. Servicing at this height above the ground, with men standing on a sloping roof, would have been difficult and expensive. Moreover, if left in the tank too long in the fall, the anodes would be lost. On the other hand, if aluminum anodes, of such size as to last only one season, were to be installed early in the spring, the fall servicing could be eliminated.

Each spring, through holes in the roof, new electrodes could be installed by hanging them from hooks on the underside of the roof plate. When connected up electrically, these new electrodes would afford effective protection for the tank bowl during the year. The whole replacement operation could be done without emptying the tank or disturbing the plant operation in any way and for that reason was a very attractive solution.

The aluminum electrodes, however, would be too far away from the riser surfaces to be of much use in protecting them from corrosion. Therefore, another type of anode was selected for the protection of these areas. This consisted of a large-size magnesium rod (or anode) hung from the top of the riser near its center and metallically attached thereto for electrical connection. The rod was required to extend the full height of the riser pipe so that all the steel surface would be protected by the galvanic action. This anode needs no power from the outside as do other types of cathodic protection devices. Such magnesium anodes are said to afford protection for about five years, so that servicing will be very infrequent.

At the North Side Sewage Treatment Works a platinum electrode has been in successful operation for about three years in a pure water tank protected by the tower of the Service Building and not subject to ice formation. The electrode is therefore removed only at rare intervals for periodic examination.

Cathodic protection, however, does not extend beyond the wetted surface. The underside of the roof and the tank side wall down to the water line are subject to very severe corrosion and must be protected in some other way.

Ordinary paints endure this exposure but a short time. The air in the space above the water is always nearly saturated with water vapor. In addition, in the atmosphere of this elevated water tank there are at times traces of chlorine, from the effluent chlorination, and hydrogen sulfide and ammonia, from a delayed decomposition of organic matter in the plant effluent water. The morning sun beats down upon the steel roof and side walls, causing them to become heated. The air inside warms up with the metal, takes on more moisture and tends to saturate the paint on the steel. Then the sun goes down in the evening and precipitation of the moisture occurs, both on and in the paint film, because of the lowering of the temperature during the night. The next day this cycle is repeated, and so on for a good many days of the year. In the winter a freezing and thawing cycle is added, which helps destroy the paint. These frequent cycles of heating and cooling, wetting and drying, freezing and thawing are very destructive of paints, especially those which absorb moisture readily from the air. For such service, a paint must be selected which has a low moisture-absorbing characteristic.

Of all the available paints known to the author, chlorinated-rubber and vinyl-resin coatings were thought to absorb the least water. It was decided to select a special type of vinyl-resin paint employed during the war on the hulls of sea-going vessels. This is really three different paints applied in series and is designated by the originators* as the WP-1 system of painting.

Before painting, the steel is first thoroughly sandblasted to an absolutely clean surface. Then a very thin coat (about ½ mil thick) of a special primer is applied, consisting of a vinyl-butral resin dissolved in an alcohol and ketone and pigmented with a type of zinc chromate having a definite chemical composition, unlike ordinary zinc yellow, which is a mixture of chemicals. Just before application, the paint is further mixed with phosphoric acid dissolved in an alcohol. This mixture must be applied within eight hours or gelation occurs.

It is a well-known fact that ordinary vinyl-resin paints do not adhere properly to steel even though the surface is sandblasted, but with the inclusion of phosphoric acid much better adhesion is secured, since the acid reacts chemically both with the steel and with the vinyl resin, thereby assuring both a chemical and a physical bond between the paint and the steel.

Moreover, the primer includes zinc chromate, which is always desirable in paints placed next to the steel because reliance is not then put entirely upon the imperviousness of the paint film, but a measure of protection is afforded by inhibition, should the water get through the film to the steel.

Over the prime coat another type of vinyl-resin paint is used as a "bond coat" to make the ordinary vinyl chloride paints adhere to the vinyl-butral primer. The bond coat consists of a polyvinyl resin dissolved in ketone and toluene and is pigmented with red lead to stabilize the vinyl. Two coats of the familiar copolymer-vinyl chloride-vinyl acetate combination, made with a white pigment, are applied over the bond coat. This vinyl paint is very tight, offering the greatest imperviousness to moisture and gas. A white-pigmented paint is used to light up the interior of the tank for inspection.

This combination of cathodic protection below and vinyl resin painting above the water line inside the tank has been completed so recently that its success is not yet determined, but the author feels quite confident that the combination will be able to conquer a very difficult problem of corrosion.

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*Bakelite Corp., New York, N.Y.

THE CONTROL OF CORROSION

By ROBERT SPURR WESTON
Late Consulting Engineer, Boston, Mass.

EVER since metal pipes have been used for conveying, and tanks and other structures for storing or moving water, their protection against corrosion has been an important problem.

What is corrosion? Broadly defined, it is the chemical action of certain external agencies which cause the deterioration of metal. Confining attention to iron, there are several established facts regarding it which are so well known that they need be only summarized.

When corrosion is in mind, one thinks of red or rusty water, stained porcelain fixtures, stained clothes from the laundry, and leaking services. Serious as these are, far more so are the economic losses due to the flow impeding products formed on the walls of pipes of water systems, with the consequent reduction in carrying capacity, and the scaling up and pitting of steam boilers. For example, a cast iron pipe having a life of 100 years under normal conditions may lose over half of its carrying capacity in 25 years because of increased friction and decreased area of cross-section due to tuberculation or other forms of rusting. Incrustation is, therefore, more important than loss of metal, for the metal dissolved from the pipe is but a small part of the mass of iron compounds, often containing organic and mineral matter, which accumulates on the corroded surface of the attacked metal.

Because chemically pure waters are the ones which are most frequently corrosive, the troubles due to corrosion have increased as better and better waters have been supplied. For example, a colored surface water will often deposit a protective coating of organic matter on the surfaces of pipes and retard corrosion; yet, when this same organic matter is removed by coagulation and filtration, the water becomes clear, is often not alkaline, and usually is so corrosive that corrective treatment is required.

Oxygen and Hydrogen—The Corrosion Team

The active agent in the corrosion of metals is oxygen, but this element would be almost powerless by itself were it not for the action of what are known as acid or hydrogen ions. Everyone knows that water is composed of two atoms of hydrogen (H) and one of oxygen (H_2O), but, according to the well-established electro-chemical theory, an extremely small fraction of a water is dissociated into H (hydrogen) and OH (hydroxyl). The familiar term "pH value" is used to indicate the concentration of these H ions. When the concentrations of H and OH ions are equal, a water is neutral and contains one ten-millionth (0.0000001) of a gram equivalent of both ions per liter.

The scale of pH values may be compared with the fine adjustment on an engineer's transit, or a vernier on a machinist's calipers. Some of the values are as shown in above table.

The interesting and significant part about this scale of pH values is the fact that the seemingly small change of only 1 in pH value actually represents acidity or alkalinity 10 times that of the higher or lower pH value. In other words, a solution with pH value of 4 is 100 times more acidic than a solution with a pH value of 6.

How refined is the scale of pH values may be realized from knowing that the pH of a good ground water containing 50 parts per million of carbon dioxide gas may be less than 6.0; of ordinary New England river waters, 6.2 to 7.6; of alum-treated filtered waters, 5.4 to 6.6; of a water of this region just saturated with calcium carbonate (chalk), about 8.4; and of a highly alkaline water, 11.0.

The pH value is so easy to determine that it is used for explanation by many operators, some of whom tend to place too much reliance upon it. Generally it determines the *rate* of corrosion rather than the amount. The *amount* is contingent largely upon the quantity of oxygen present. Theoretically, the acid ion (H) attacks the metallic iron; then the oxygen combines with the iron, releasing the H ion for a further attack, and the cycle moves on. Consequently, the lower the pH value the higher the acid concentration and consequent *rate* of solution.

	Concentration (Grams Equivalent Per Liter)	pH Value
Acid hydrogen (H) ions predominate in this zone above the neutral line	1.0	0
	0.01	2
	0.0001	4
	0.000001	6
NEUTRAL CONDITION	0.0000001	7
	0.000001	8
	0.00001	9
	0.0001	10
Alkaline (OH) ions predominate in this zone below the neutral line	0.001	11
	1.0	14

Signs of Corrosion

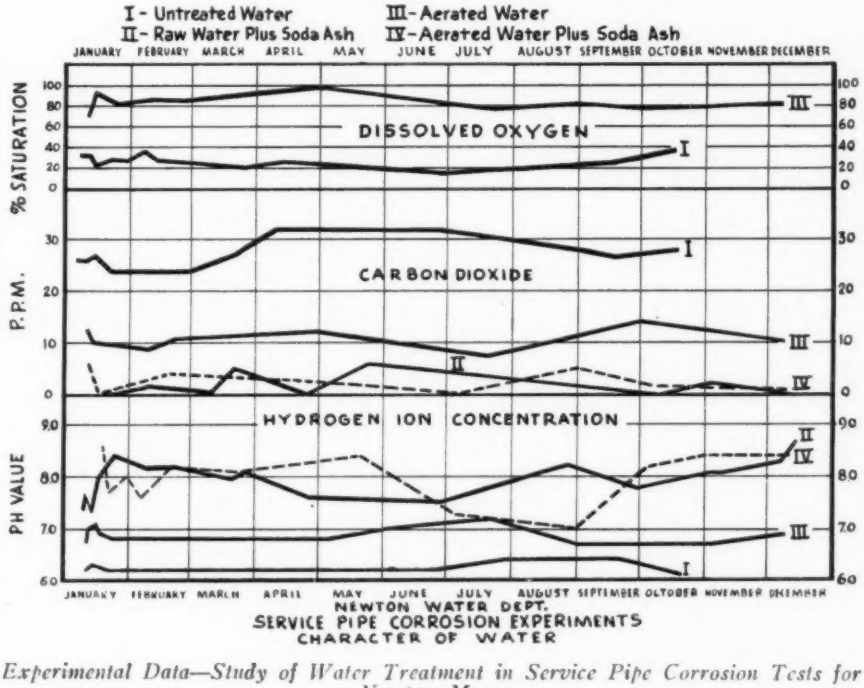
The well-known signs of corrosion are the black or green ferrous (unoxidized) rust formed next to the metal, and the reddish brown ferric (oxidized) rust at the surface, with mixtures of the two between. Some coatings are dense and retard corrosion. Some are porous and slow it down but little. Because the susceptibilities to corrosion vary greatly over the surface of the metal, the action is frequently localized in the form of tubercles, as, for example, where a protective coating inside a pipe is impenetrable except in spots. The dislodgment of rust coatings or tubercles causes the well-known "red water" troubles.

In New England, there are some well waters low in pH value, and corrosive, but which form no coatings of rust inside the pipes, and come clear at the taps. Usually these contain iron in solution and there is a streak of red rust on tub or bowl where the dissolved iron oxidizes and collects.

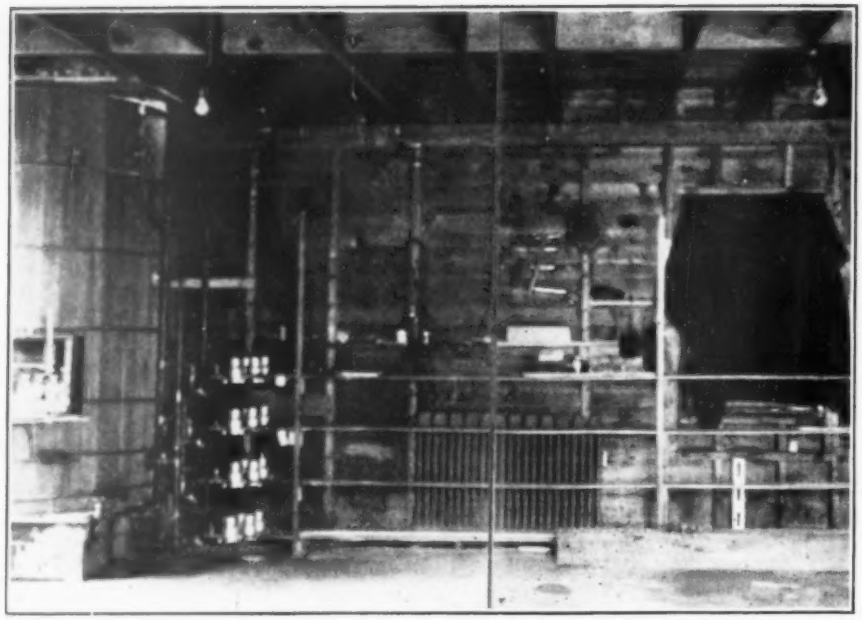
The pH value and oxygen content are not the only factors in corrosion. In natural waters the organic contents, or sulfates, carbonates, chlorides, and other salts—of calcium and magnesium particularly—reduce or modify the corrosive action of waters or affect the protective treatment required. A good critical review of modern theoretical researches with references to the works of Baylis, Langelier, Enslow, Hale and others, has been recently given by Prof. Edward W. Moore[1] of the Harvard Graduate School of Engineering.

Correction and Control

Obviously, with acid waters containing oxygen,—and most of them do,—it is well to reduce the acidity or increase the alkalinity by the addition of an alkali. For this purpose two chemicals have been used extensively, namely: carbonate of soda (soda ash), and hydrated lime—Na_2CO_3 and $Ca(OH)_2$.


I - Untreated Water
II - Raw Water Plus Soda Ash
III - Aerated Water
IV - Aerated Water Plus Soda Ash
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER
% SATURATION
DISSOLVED OXYGEN
P.P.M.
CARBON DIOXIDE
PH VALUE
HYDROGEN ION CONCENTRATION
NEWTON WATER DEPT.
SERVICE PIPE CORROSION EXPERIMENTS
CHARACTER OF WATER

Experimental Data—Study of Water Treatment in Service Pipe Corrosion Tests for Newton, Mass.



Corrosion Study Installation of Various Service Pipes for Evaluating Anti-Corrosion Treatments at Newton, Mass.

Soda-Ash

When soda ash is used, little or no insoluble coating, except iron hydroxide, is formed on the iron, and when it is added to a colored surface water, the color may be increased which is objectionable. Nevertheless it has its uses. A case at point is that of Newton, Mass.

Before 1928, the city of Newton was supplied with water from wells. Later on, conditions demanded the construction of infiltration basins which are filled from the Charles River and which are used to increase the supply from the wells. The effect was an increase in the amount of oxygen and a decrease in the amount of carbon dioxide, with resulting increase in corrosion. Brass pipe was short-lived and there were blue stains on bowls and baths where copper pipe was used. Iron, of course, was attacked also.

A series of experiments[2] were planned and carried on for about a year, using

(a) Untreated water;
(b) The regular supply treated with enough sodium carbonate to raise the pH value to 8.0;
(c) Aerated water;
(d) Aerated water treated with enough sodium carbonate to raise the pH value to 8.0.

The results showed that by adding enough sodium carbonate (soda ash) to maintain the pH value of the delivered water at 7.6 the action on the brass and copper pipes was arrested and the corrosion of the iron piping came within the limits of tolerance.

Consideration was afterward given to the addition of lime, but it was not adopted because of the increase in hardness which would result.

Lime

Lime, when added to certain waters in sufficient amount, produces a coating of calcium carbonate (chalk) on the surface of pipes and metals, and is an effective agent. However, ordinary soft local waters dissolve about 30 parts per million of calcium carbonate at a temperature of 20° C. (68° F.); consequently, when lime is added to these waters in sufficient amount, the hardness of the water is appreciably increased, sometimes to an objectionable degree. To saturate these waters with calcium carbonate, it is necessary to raise the pH value to about 8.4, with a consequent noticeable increase in hardness.

Character of Raw Water and Effects of Treatment With Soda Ash, Newton, Mass.

Results of Analysis (Parts Per Million)

Constituent	PUMPING STATION Untreated	Treated	Supply Yard
Turbidity	0.	0.	0.
Color	2.	5.	5.
Alkalinity	26.0	74.0	72.0
Hardness	29.9	29.9	31.2
pH value	6.2	7.8	7.6
Iron	0.08	0.10	0.08
Carbon dioxide	25.0	4.0	4.1
Dissolved oxygen % saturated	33.8	.....	.....

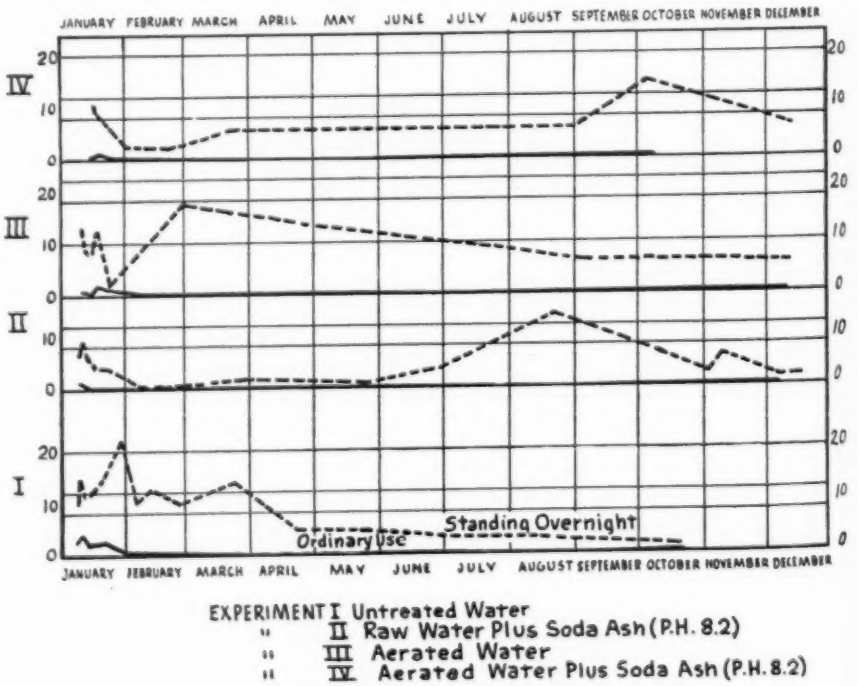
In practice, one adds enough lime to keep the pH value below 8.4 in order to avoid incrusted meter parts and piping, and above about 7.8 to keep the consumers from ringing the superintendent's telephone to complain of red water. Under these compromising conditions, there is necessarily some corrosion but usually it may be controlled by adequate flushing of the mains.

Silicate of Soda

In some cases sodium silicate (water glass) is added also, say, in small amounts with the lime, or say once a week or ten days, in larger amounts. The calcium silicate, so formed, is less soluble than the calcium carbonate and helps to maintain a protective coating on the metal. This is the practice at North Attleboro, Mass., and was the practice at Winchester, Mass., until a change was made by substituting sodium hexametaphosphate, which is more generally known as "Calgon." Concerning "Calgon" treatment more is to be said later.

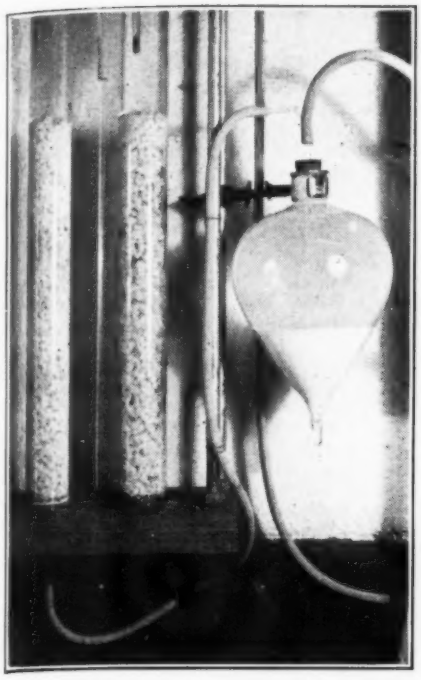
The object of the addition of lime or any other chemical is to limit the attack of the water by holding the products of corrosion at the boundary surface of the metal in the form of a thin layer. Rust alone is too porous for protection, but rust plus calcium carbonate (chalk) is generally effective. Moore[1] has referred to the work of Langelier who devised the formula for establishing the equilibrium of any water with calcium carbonate, and consequently the proper dose thereof; also that of Enslow who devised a convenient apparatus for determining continuously the widely varying degree of saturation for waters ranging in hardness or alkalinity from less than 10 to nearly 1,000 parts per million.

This apparatus saves the time of chemists in making the so-called marble test, devised by C. P. Hoover, or in arriving at the Langelier index of corrosivity, which, as stated, determines the proper dose of lime.



Experimental Data, Newton, Mass.

The effect of various treatments in subduing attack on black iron pipe reveals ppm. iron dissolved by flowing water as compared with water standing in the pipes overnight and recorded by dashed lines.



The Enslow Continuous Stability and Corrosivity Indicator

The simple and inexpensive Enslow Corrosivity Indicator is described in Reference and Data Numbers of WATER WORKS AND SEWERAGE for 1941 and 1942.

It was soon found, however, that the effects of lime treatment alone did not reach the dead ends of the system until after a considerable period, and frequently not until an undesirable accumulation of deposit had occurred near the point of application of chemical.

This is illustrated by the experience at Wakefield, R. I. where an old works has been supplying water to industrial and mercantile villages, summer and pleasure resorts over a wide area. The colored raw water is from surface sources, and for about fifty years was supplied untreated; but, while there was an accumulation of organic matter in the mains, few complaints were aroused because of corrosion.

In 1930, the works postponed the construction of a water purification plant by adding chemicals to the inlet of the lowest reservoir in the system and using it as a coagulating and clarifying basin. This was a beneficial but temporary practice, and, in 1940, after a study of the possibilities of ground water supply, pressure filters were installed and the water was treated with alum, with no provision for flocculation. The resulting acid water (usually clear and low in color) caused dislodgements and corrosion. Lime was added, sometimes in excess, and this accumulation, with the older ones, was often dislodged and caused complaint.

Experiences with "Calgon" Treatment

To delay the carbonate precipitation, and to avoid the addition of an excess of lime, the application of sodium hexametaphosphate was resorted to.

This chemical, sold under the trade name of "Calgon," was first used to delay or inhibit the after-precipitation of calcium carbonate in water softening; and, later, to cause the gradual coating of the out-lying parts of the distribution system, and to reduce accumulations near the source of supply. It was also believed that the phosphate would not only prevent excessive deposition, but, when added alone, would inhibit corrosion because of its power to form a thin protective film (said to be a molecule thick) on the surface of metal with waters having pH values on the acid side of neutrality.

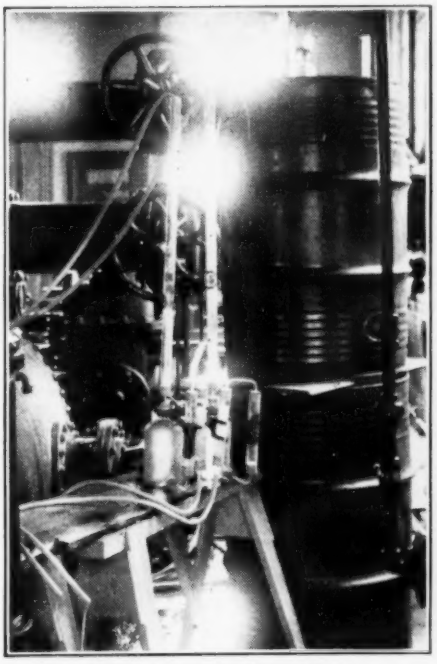
The writer's first experience with this chemical was at Fairhaven, Mass.[3] Here, the raw water from wells was slightly corrosive and contained enough iron to form deposits, but too little to warrant its removal by the usual methods. Here, the metaphosphate has been employed successfully. It has controlled corrosion and has kept the iron in suspension, even at the dead ends.

Early in 1941 it was decided at Wakefield, R. I., to apply metaphosphate and to gradually reduce the dose of lime at the same time. Application of metaphosphate was begun on May 6th. Application of lime to the filter effluent was gradually reduced, and was discontinued on August 16th. Metaphosphate was applied first at the rate of 4 ppm., and later at the rate of 2 ppm. While it may be too early to give a true picture of the results, they have been satisfactory. The older chalky deposits have been removed from most of the system. "Red water" troubles have nearly ceased, and flushing of the mains is attended with less and less sediment. The present indications are that a lower dose of metaphosphate will suffice.

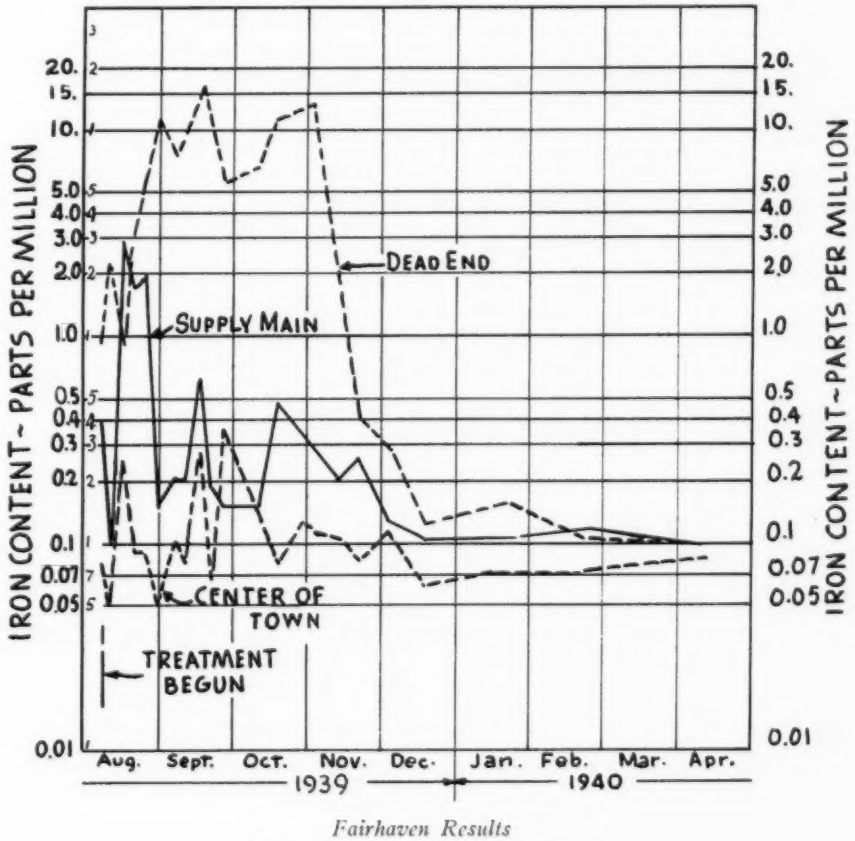
In the 21 months of operation, by gradually reducing the lime dosage, the pH value of the delivered water has been reduced from 8.8 to 5.2 at the filters and 6.0 at a point on a branch line four miles away.

Experience with metaphosphate is still too limited, and waters vary so much in their requirements, that it is not yet possible to generalize with accuracy regarding its effects. It is found that it is an inhibitant when present at a concentration of a few parts per million, even when the pH value is low. It protects iron and copper when the pH is high. On the other hand, it behaves differently when in solution containing from 0.1 to 1.0 per cent or more. Here it forms complexes with calcium, magnesium, iron, aluminum, zinc and tin.

At Wakefield, R. I., the soldered joints in the copper feed tank, used to apply the chemical, were dissolved rapidly, as was the galvanizing on a steel drum used to store the solution. Apparently, welded black iron,



Experimental Installation at Fairhaven, Mass.
For studying effect of "Calgon" and other corrective treatments.



Fairhaven Results
The effects of "Calgon" Treatment.

stainless steel, rubber and glass are the best materials for use in contact with strong solutions of hexametaphosphate.

Even the apparent protection given iron pipes when waters of low pH value, containing one or two parts per million of metaphosphate, are passed through them is somewhat in doubt. This statement is made because the chemical is so good a dispersant of iron and other metals that it would prevent the usual red stains from appearing on basins and bowls.

A reading of the report of the round table discussion on corrosion control at the New Orleans meeting of the American Water Works Association in 1938,[4] followed by a reading of the Committee report[5] on the value of sodium hexametaphosphate in the control of difficulties due to corrosion in water systems, published four-and-a-half years later, will give one an idea of the varied and complex character of the problem.

With the above report is a contribution by Dr. F. E. Hale which warns one not to make the mistake of believing that hexametaphosphate prevents the corrosion of iron by soft waters of low pH value, even when the delivered water is of good appearance, free from red water and causes no increase in friction in the mains.

In this connection one must bear in mind the large amount of iron in the pipe system and the small amount in the treated water. In a works discharging 200 million gallons yearly containing 0.10 ppm. of iron dissolved from the mains, the weight of iron lost would amount to only 167 lbs. per annum while the amount of cast iron pipe in the distribution system might weigh from 20 to 30 million pounds, or even more. This does not mean that the possibility of leakage at nipples and joints should be dismissed as negligible or that solution of metal should not be watched. It probably does mean that a better condition than where tuberculation and incrustation with attendant loss in capacity occurs, and which the metaphosphate treatment minimizes or prevents.

Cathodic Protection

During the last few years many waterworks have resorted to electrolytic treatment designed to reverse the ordinary electrolytic action of water. To do this, electrodes are placed in standpipe or filter shell and current is passed from the positive electrode in the water to the negative electrode on the metal, with the result that instead of the corrosive H ion reaching the metal the non-corrosive alkaline OH ion takes its place.

This method, when applicable, is efficient and its cost of operation is low. The chief objection to it, in standpipes particularly, is the effect of ice, which often carries away the electrodes. Fortunately, however, the electrodes can be removed for a few weeks during the winter when corrosive action is lowest. Apparently the protection given the metal during the warmer months of the year is prolonged for a considerable period beyond the time of removal of the electrode.

Naturally, more trouble is experienced when this type of apparatus is used with surface waters than with ground waters, because the temperature of the latter rarely falls below 45° F. as compared with 34° F. for surface waters.

Cathodic protection can also counteract another type of electrolytic corrosion, sometimes called battery action. For example, where two metals, like copper and zinc, are in contact and immersed in water, the zinc goes into solution, an action which countercurrent, afforded by cathodic protection, would neutralize if properly controlled.

In General

In considering the control of corrosion, one must bear in mind that waters vary greatly in their characteristics and action. Consequently, it is extremely difficult to prescribe the best remedy for corrosion control without some actual tests, like those made by the city of Newton. For this purpose, makes of pipe are subjected to the action of treated and untreated waters under conditions of ordinary use and standing overnight for a sufficiently long period to determine what is best for control of corrosion.

References

(1) Corrosion Control. Prof. Edward W. Moore, *J.N.E.W.W.A.* **55** (1941), 265.

(2) Experiments on the Newton Water and Treatments for the Control of Corrosion. F. W. Gilcreas, *J.N.E.W.W.A.* **48** (1934), 105.

(3) Corrosion Control by Metaphosphate. H. T. Gidley and R. S. Weston, *J.A.W.W.A.* **32** (1940), 1484.

(4) Corrosion Control. Wiggin, Norcom, Glace et als. *J.A.W.W.A.* **30** (1938), 1342-87.

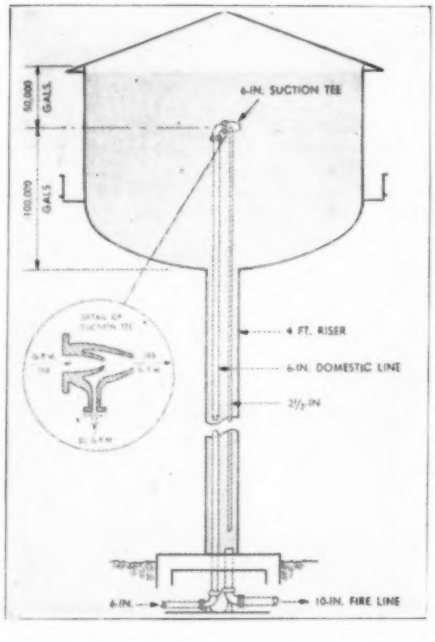
(5) Report of Committee on Water Conditioning Methods to Inhibit Corrosion. E. W. Moore, Chairman. *J.A.W.W.A.* **34** (1942), 1807-1828.

NOVEL SCHEME FOR PREVENTING TANK RISERS FROM FREEZING UP

Out at Grand Canyon, in Arizona, it gets pretty cold and during the winter season there is but little turnover in the elevated water tank, the chief duty of which is fire sprinkler service during the off resort season. To avoid the solid freeze-up of the tank riser during the low winter turnover period, Santa Fe Railway engineers developed a unique scheme of intermittently circulating water from the bottom upwards through the riser.

The scheme in question has been in successful use now during 15 winter seasons. Briefly, it involves the installation of a suction tee educator (Watson and McDaniel) on the end of the filling pipe. A 2½-in. drop suction line from the educator picks up water at the rate of 30 gpm. from the bottom of the riser and discharges it into the center of the tank to mix with the warmer water. While an ice shell of 2 in. thickness has been found in the riser, the circulating scheme has prevented further ice shell encroachment.

This information originated from G. L. Davenport, Jr., division engineer of water supply, Santa Fe Railway System, Los Angeles.



Schematic Sketch of Riser Recirculating System

"GOVERNMENT" WHITEWASHES

The following formula is commonly known as "Government Whitewash." It is used on lighthouses and other places exposed to the weather, and does not peel off.

Carefully slake one-half bushel (38 pounds) of good quicklime, covering during the process to keep the steam in. Strain the paste while still thick through wire fly screen cloth and add about four gallons of water. While stirring vigorously, pour into the lime mixture a solution made by first dissolving 12 pounds of salt and 6 ounces of alum in about 4 gallons of hot water. Then add one quart of molasses and thin with water to suit requirements.

Another method is:

Using one-half bushel (38 pounds) of good unslaked lime, slake with boiling water and keep covered during the process to keep the steam in. Strain the liquid through a sieve fine enough to retain all unslaked lumps. Dissolve a peck of clean salt in a little water and add to the solution. Boil to a thin paste three pounds of rice and put into the mixture, while hot, and one pound of glue, previously melted over a fire. Add one-half pound of whiting. Mix well and then add 5 gallons of hot water, stirring well. Cover closely and let stand several days.

If the whitewash can be applied when hot, it will go on better and last longer. Coloring matter may be used to vary the tint to suit the taste.

LIMESTONE CONTACT BEDS FOR CORROSION CONTROL

Have Features Attractive for Small Installations

By I. M. GLACE, C.E.
Consultant and Supervising Engineer, Harrisburg, Pa.

THE water served Dillsburg, Pennsylvania, is typical of that of many other similar supplies serving the considerable number of communities located in or contiguous to the Appalachian Mountains in Pennsylvania.

The following analysis of the Dillsburg water is characteristic of water of the territory—very soft and palatable, but corrosive and tuberculating:

Hardness	12 ppm.
Alkalinity	8 ppm.
Carbon dioxide	20 ppm.
pH	5.4

From a bacteriological standpoint the water is of high quality.

Complaints

Tuberculation of the mains had resulted in a noticeable decrease in carrying capacity and pressure losses at fire hydrants. In order to cooperate with the local fire department the water company, which is exceptionally progressive for a community of this size (1,054 inhabitants in 1944), retained a nationally known water main cleaning company to scrape the lines. From the standpoint of recovery in main carrying capacity this operation was a success. Naturally, the cleaning exposed some fresh metal, and complaints of "red water," laundry stains, and iron tastes were received by the company. It was then that the writer and the Wayne Laboratories, with whom he is associated, were retained to recommend relief measures.

Consideration was given first to standard methods for the control of corrosion through the application of hydrated lime, other alkaline salts, to boost pH values. Such a procedure, however, requires more or less constant attention and close chemical control to be really effective. Moreover, the cost of the operations, for a small company, is excessive and remoteness of the proper point of application at Dillsburg would make it more so. A search was made, therefore, for some easier solution of the problem, one which might be less exacting in control.

Limestone—Nature's Corrective

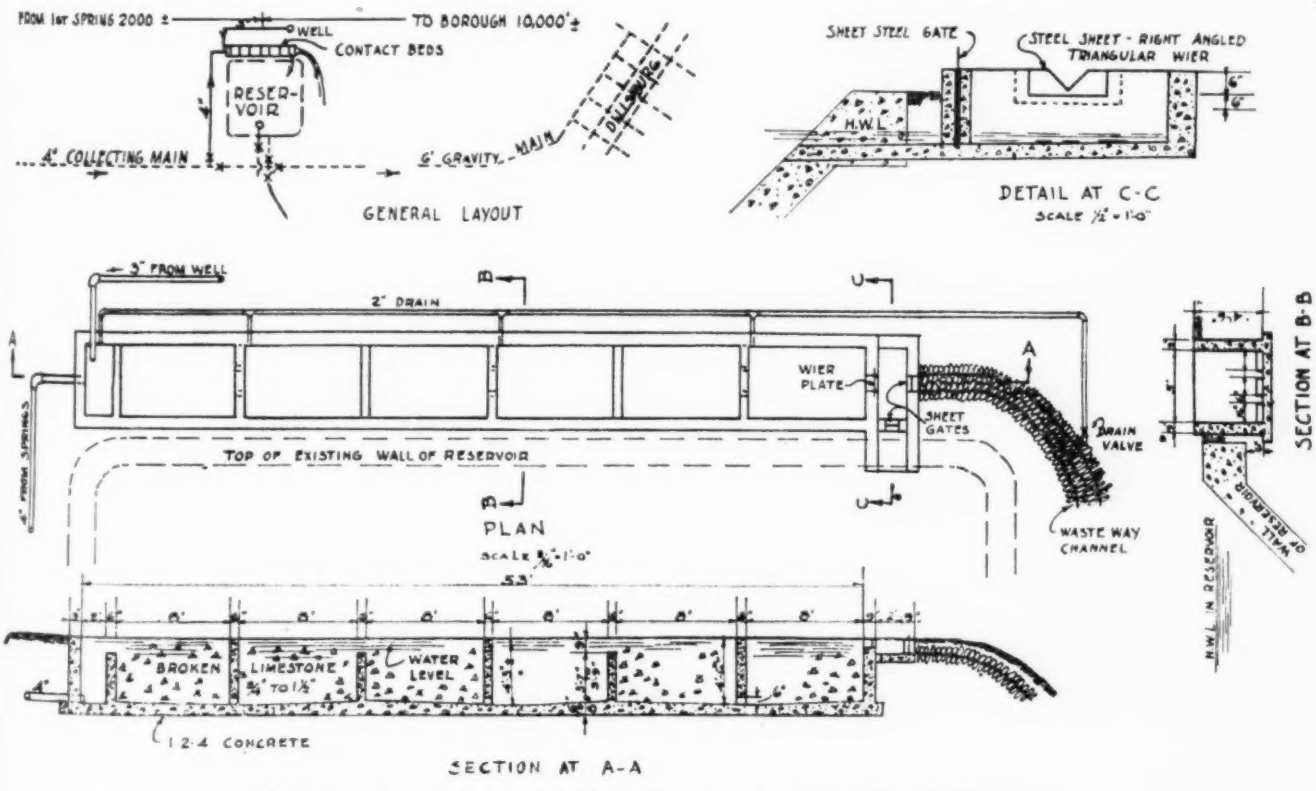
The suggestion was made by Wayne Laboratories that beds of limestone be prepared and the spring water passed through for treatment. In the absence of concrete information and technical data on such treatment no attempt was made to put such a plan in operation because lime treatment seemed the more positive and certain method.

At about this time an article appeared in *Water Works & Sewerage*, under the name of Henry Ryon, describing the experimental work and full plant scale results at a state institution on Long Island, where crushed marble contact filters had been installed for the correction of a well water which has practically the same characteristics as that of the spring water at Dillsburg.

Using the Ryon data, from *Water Works and Sewerage* as a guide, an experimental unit (here sketched) was installed at Dillsburg. It was continuously operated for almost a year before determining on the plant scale design and practicability of the scheme, under winter conditions, life of the marble or limestone, and other important practical considerations, such as cloggage, difficulties and the like.

The incoming raw water and the outgoing treated water were metered as shown, using standard ⅝-inch service meters; the feed and discharge lines were of new galvanized iron pipe. The 50 gallon wooden barrel, and the terra-cotta pipes which serve as baffles for proper distribution through the tank, are filled with broken (high-calcium) limestone of about 1 inch size. The flow of water was regulated during most of the period at a rate of about 220 gals. per day, or slightly less than a pint per minute. It is interesting to note that this small amount of water was measured quite accurately (within a five per cent error) by the meters, as checked by volumetric determinations. The influent meter was operating under a head of only about one foot.

At this low rate of flow it is estimated that the water in its passage through the tank had a 2 hour contact, based on approximately 50 per cent voids in the limestone bed.



Limestone Contact Beds at Dillsburg, Pa. Capacity Better Than 50,000 gpd.

Observations and Deductions

At the end of the first six months' run, the inlet and outlet pipes and the meters were dismantled and examined. The inlet pipe was already tuberculated and badly stained. The inlet meter likewise was heavily stained, but not tuberculated. The outlet pipe, on the other hand, showed no iron discoloration, and no tuberculation or pitting, but was covered with a soft and very light gray film. The outlet meter was not affected one way or the other.

The limestone at the top of the down-flow (inlet) compartment, was also excessively stained but the stone surfaces at the outlet side were as clean apparently as on the day they were placed.

During this six-months period the rate of flow was uniform, it being controlled by means of a drilled coin union placed in the inlet line. Later a larger orifice was inserted and the rate tripled, with an immediate decrease in the efficiency of the treatment being noted.

Based on a number of determinations made in the field and in the laboratory (with results averaged), the experimental unit produced a very consistent effluent as follows:

	Raw	Treated
Hardness	12 ppm.	28
Alkalinity	8 ppm.	24
Carbon dioxide	20 ppm.	2
pH	5.4	7.4

The practical benefits of a non-corrosive water have recently been well demonstrated by the New England Water Works Association, in its report on Pipe Line Friction Coefficients, which emphasizes the inter-relationship between calcium carbonate, alkalinity, and CO_2 content, and the value of pH of the supply as an index of rate of capacity loss. The figures given above seem to be in agreement with the findings of the committee.

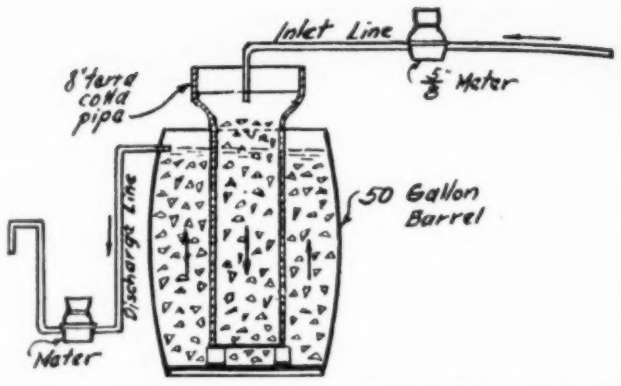
Full Scale Operation

As a result of this experimental work the full scale plant shown in Fig. 2 was installed at Dillsburg. The data secured in its operation confirm the experimental observations.

The pH, alkalinity and hardness of the treated water have increased to about the anticipated extent, with corresponding decreases in CO_2 content. Average figures on the raw and treated water are as follows:

	Raw Water	Treated Water*
pH	5.4	7.3
Alkalinity	12 ppm.	44 ppm.
Hardness	8 ppm.	40 ppm.
Carbon Dioxide	20 ppm.	5 ppm.

*2½ hr. contact period



Experimental Calcium Carbonate Contact Bed Set Up and Operated in Corrosion Control Studies at Dillsburg, Pa.

The effect on the pH of the water is shown in the following tabulation:

Sample Location	pH	
Inlet	5.4	
1st Baffle	6.8	
2nd Baffle	7.1	
Outlet	7.2	(2½ hr. detention)
Reservoir	7.5	
Consumer's tap	7.6	

The rate of solution of limestone seems to be about 22 lb. per mil. gal. This is a "dosage" of approximately 1 grain per gallon.

On the basis of the original cost of the broken limestone, the cost of the "chemical" has been approximately 15 cents per mil. gal.

The total cost of the completed project was about $1,000 for the plant capable of treating 50,000 gal. per day. This cost included the broken limestone.

From the consumer's standpoint, as well as that of the company, the treatment has been a success. Iron and other metallic tastes have disappeared; complaints of stained laundry, formerly frequent, are no longer received. There is a marked reduction in the servicing necessary to meters. The only drawback is the slight increase in hardness, but three grains of hardness is still a reasonably soft water.

The results to date have definitely surpassed expectations and the method has proved very attractive.

COAGULATION WITH FERRIC SALTS*

With Particular Reference to Ferric Sulphate and Its Use

By J. B. NICKEL
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ALL water works operators are probably familiar with one form or another of coagulation with iron salts. There is an aversion among most water works operators toward iron salt coagulation, this aversion being improperly founded and probably arising from difficulties encountered in coagulation with ferrous sulphate. Although this paper is devoted to coagulation with ferric sulphate, a brief review of coagulation with other types of iron coagulants will clarify the inherent differences between coagulating with ferrous salt and ferric salt.

Ferrous Sulphate as a Coagulant

The most common form of iron coagulation, that is the one most familiar to all of us, is coagulation with ferrous sulphate and lime. This form of coagulation has been called, by many authorities, the most economical means of water coagulation. I do not entirely agree with this statement, however, since many of the difficulties encountered with the actual coagulation drive up the total cost to the point that economy is hardly a consideration.

Ferrous sulphate itself is water soluble and will remain in solution in any water near neutral pH over a long period of time. In order to have any coagulating value whatsoever, the ferrous sulphate must be converted to a ferric salt. This is normally accomplished by raising the pH with lime and then adding the ferrous sulphate. In the presence of dissolved oxygen the reaction produces ferric-hydroxide, the same coagulating material obtained with almost any ferric salt. A certain portion of the ferrous sulphate, however, must be converted to ferric-carbonate which has absolutely no coagulating value. From this it can be readily seen that only a portion of the iron actually available in the ferrous sulphate is utilized in coagulation. Furthermore if excess lime is added, an unbalanced water may be made and the sand grains on the filters may be seen to grow If an insufficient amount of lime is used, some of the ferrous sulphate will remain in solution and will pass the filters still in solution. This will cause red water difficulties in the distribution system as well as causing inefficiency in the actual coagulation process.

These difficulties alone are sufficient to rule against the use of ferrous sulphate and lime in most water purification plants. Ferrous sulphate, however, has a tendency to cake and cannot be normally used in all types of dry feeders due to this tendency If stored in large bulk hoppers, it is often known to cake in these hoppers and may even require the use of air hammers to break it. The most common method of storing ferrous sulphate is of course in water proof bags and most plants do use the material in that form.

Ferrous sulphate can also be used with chlorine This treatment is normally known as the chlorinated copperas treatment. The ferrous sulphate is first put into solution and then chlorine is added in a ratio of approximately one to seven. The chemical reaction produces a mixture of ferric-sulphate and ferric-chloride. This is a very excellent coagulant and certainly will do a fine job of coagulation. The objections to this type of treatment, however, are that the ferrous sulphate is still difficult to feed and furthermore the chlorination of the copperas causes fuming and unless the process is properly protected, corrosion of the surrounding apparatus often occurs. Furthermore, this feeding apparatus is rather expensive and must be rather carefully controlled at all times.

Ferric Chloride

Ferric chloride is not normally employed in water plants due to its physical characteristics. The anhydrous material is far too expensive to use. The liquid material, although a cheap coagulant if the plant is located near a source of manufacture, requires rather expensive equipment for handling. All unloading equipment must be rubber-lined, and rubber-lined storage tanks must be provided, all feed lines must be rubber-lined and in the end a very expensive installation is required.

Ferric Sulphate

Ferric sulphate has been long recognized by the general water works trade as an efficient coagulant but its general use was not adopted due to a very high price of the chemical. Until a relatively few years ago, in fact during the last decade, ferric sulphate was considered too expensive for normal use in water treatment plants. At that time, however, two manufacturers started making this chemical as a by-product and the price now approaches that of filter alum. Therefore, with the rather high cost of securing this chemical eliminated, its use began to pick up rapidly in water and sewage plants throughout the United States.

Unfortunately, however, for the water works industry as a whole, the war has presented a very rapid expansion of its use. In the first place, ferric sulphate is used in the pickling of stainless steels and brass and is used in the catalysts for the manufacture of synthetic rubber, it is used in the manufacture of certain types of insulating boards, it is used in the manufacture of foam fire extinguishers, as well as many other industrial uses

All of these industrial uses have claimed a large percentage of the total production of ferric sulphate during the war period. Furthermore, there are certain processes in the manufacture of ammunition powder that even the slightest trace of alum would disrupt. Therefore some coagulant other than alum had to be resorted to. In most instances, these plants are now using ferric sulphate With the end of the war ferric sulphate has again become available for new water works contracts Were it not for these facts there would undoubtedly have been a much broader use of ferric sulphate by now.

Dissolving Ferric Sulphate

Ferric sulphate is not difficult to use but its use is different from that of alum and certain considerations must be made. In the first place, ferric sulphate is by no means as soluble as alum. This requires the use of different types of dissolving equipment. Ferric sulphate, peculiarly enough, is more soluble in a small rather than in a large volume of water due to the fact that a more acid solution is rendered and secondly because the heat of solution of ferric sulphate is not dissipated and a warmer water is obtained in the dissolving pot. Normally, it is considered that the proper water salt ratio is three parts water to one part of ferric sulphate by weight.

The ferric sulphate is first fed into a dissolving pot and water is added in the proper ratio. The material must then be violently agitated for a period of about thirty minutes before it goes into solution. This may sound rather complicated but it is a relatively simple process to put the material into solution.

This dissolving pot is not large. For example, take a water plant treating twelve million gallons of water per day with a maximum dosage of three grains per gallon. For maximum feed conditions, a twenty minute retention period in the mixing pot and a two to one water ratio are normally sufficient. Under such conditions a twenty gallon crock would be a sufficiently large solution pot. A larger solution pot could of course be used without difficulty if it should be desired to do so.

Metering is relative simple; a rotameter is probably the most common metering device for this purpose and such a rotameter should read directly in pounds of water per hour, and should be so selected for size that the rotor rides about half way in the tube for normal operating conditions. The Omega Machine Co. has made an Archimedes wheel as a measuring device for water on such feeders or a very simple home-made device can be utilized which is merely feeding the water into a constant level box, the overflow going to the dissolving pot outlet, and the water to the dissolving pot controlled by a pinch cock.

The dissolved material from the solution pot is very strong. This should be further diluted before going to the raw water. In fact, a 2 per cent solution has been found to be most satisfactory for ferric sulphate or alum, or any other coagulant for that matter. Of course this 2 per cent solution strength need not be accurately maintained and need be only approximated. It seems that any stronger solution will have a tendency to react with only a small portion of the raw water thus failing to give a uniform coagulation of the entire mass of water

Solution Pot Equipment

Agitation of the dissolving pot is best secured by a small type mixer, probably a ⅛-hp. portable mixer This should be

* This paper, presented before the W Va Section of the Am Water Works Assn., is here published by permission of the Association

of the "Lightning" type or similar, normally costing from $75 to $85 each. Complete installation for the average small feeder will run approximately $100 per feeder to install the proper dissolving equipment.

It is interesting to note here that most plants having tried ferric sulphate have resorted to this type of dissolving equipment even though they are still using alum. They have found that this type of dissolving equipment accomplished several advantages even with alum. In the first place, they are able to maintain a true solution of alum and thus all the alum fed is utilized. In many studies it has been found that much of the alum going into the raw water was undissolved. A sizeable portion of this material settled out into the sludge and never did properly react with the water. Still other material was carried beyond the mixing basin before becoming properly dissolved and thus carried free alum through the filters. This not only wastes alum but is not a condition to be desired in any plant. This change in method of dissolving alum is particularly noticeable during the cold weather. Many of the cold weather problems of plants using this solution pot dissolving technic have been eliminated.

It is interesting to note that the new Fall Creek plant at Indianapolis, Indiana, built only a few years ago, employs a large stainless steel dissolving pot, agitators, rotameters for controlled alum solutions, plus controlled water temperature for feeding to the alum thus assuring a complete solution of a known strength at all times. This plant has been most economical in its operations.

The blades and shaft of the agitators must be of some acid resisting material. Probably the most common is 18-8 stainless steel. This is strong and at the same time gives excellent wearing qualities. Wooden paddles and shafts or wooden shafts and porcelain impellers may be used equally well, but are not quite as long-lived as stainless steel.

The best material for the dissolving pot is probably lead, but other materials may be used. Stainless steel is very good but it is too expensive for the average plant. Rubber-lined steel tanks are excellent but if the temperature in the pot should rise above 140° F, the rubber lining is damaged and the pot may fail. For this reason it is not generally considered the best practice to use a rubber-lined dissolving tank. Lead-lined dissolving pots are satisfactory but lead-lining is so thin that the abrasion from the insoluble particles of ferric sulphate may cause it to wear through rather rapidly, thus allowing the material to attack the iron or steel of the pot shell and thus cause leaks. Crockery and Duriron are both very satisfactory for the dissolving pot but both have the same disadvantage in that they are brittle and are rather easily broken by impact. Wood dissolving pots are quite satisfactory but have the disadvantage of requiring an appreciable amount of maintenance to keep them coated with some acid-resisting paint.

The lines from the dissolving pots to the point of application must also be given consideration. These lines may be of any acid resistant material. A rubber-line is preferred as it is easy to clean out and cheap to install. Rubber-lined steel lines are used in a number of plants and are very satisfactory. Lead pipe may be used very satisfactorily, particularly if it is protected from damage from impact.

Equipment for handling ferric sulphate up to the point of solution is exactly the same as that for handling alum. The material is no more corrosive than alum in the dry state. Thus any standard dry feeder is satisfactory for the material. Ferric sulphate will store in bulk hoppers, bags, or other means the same as used for storing alum in any plant. It does not arch in the feeders and will store over long periods of time without lumping.

Floc Formation

Ferric sulphate is somewhat more active chemically than alum and the hydroxide is produced more rapidly than is the case with alum. This means that the mixing characteristics of the plant should receive additional attention if ferric sulphate is to be used. The coagulants should be added at the point of maximum agitation. The quick mix is very important if good coagulation is to be obtained. A hydraulic jump probably is the most rapid and complete pre-mix but there are a number of mechanical pre-mixers that give excellent results. The object of the pre-mixers is primarily to distribute all the chemicals throughout the main body of raw water before the chemical has sufficient time to react with the raw water. This means that a violent mix is to be preferred although any mix that works satisfactorily for alum should work satisfactorily for ferric sulphate. The coagulation or slow mix should normally be a little bit longer than that employed for alum. Alum *starts* to form its floc more slowly than ferric sulphate; then the floc forms very rapidly, and additional mixing beyond that point does little or no good.

On the other hand, with ferric sulphate, the floc starts to form immediately from the introduction of the chemical into the water and floc development continues at a rather slow and uniform rate for approximately forty minutes before it starts to level off. This floc formation time will of course depend on water characteristics, temperature and other variables but forty minutes may be considered the general rule. Ferric sulphate of course works excellently in many plants employing much shorter mixing or coagulating periods but these plants probably are not operating at maximum efficiency and even greater savings would be possible if longer mixing periods were possible.

Characteristics of Ferric Sulphate Coagulation

With this information on the method of feeding ferric sulphate it might be well to consider some of the characteristic reactions within the plant. Ferric sulphate is far less touchy to turbidity changes than is alum. That is, a change of turbidity that would require a change of dosage for alum coagulation, may require no change of dosage with ferric sulphate. For instance, one plant on Lake Michigan using ferric sulphate regularly, has machines set for a specific dose at all times. Variations in the turbidity of the lake water, although relatively small, are noticeable with alum coagulation but are not noticeable with ferric sulphate coagulation. Likewise a mid-west plant is subject to rather high flash turbidities which do not cause any particular trouble. True, the dosage should be increased for higher turbidities as a safety factor but as long as just a small excess dosage is being used, a considerable change in turbidity may occur and yet good coagulation can be maintained throughout this period. This fact is quite helpful in plants where highly trained operators are not available at all times.

The percentage of iron in ferric sulphate is higher than the percentage of aluminum in filter alum. Therefore ferric sulphate is generally considered a stronger coagulant. This means that considerably smaller dosages can normally be used. In many plants, it is found that from thirty to forty per cent less ferric sulphate can be used than alum. This is not true in all water plants, however, and cannot be taken as an absolute rule. Always bear in mind that both coagulants have their place in the water works field and no absolute positive rule regarding their comparative performance can be laid down.

Ferric sulphate is particularly advantageous in water softening plants. It is not sensitive to changes in pH in the high pH range encountered in softening. The very careful pH control required in softening plants using alum coagulation is not essential in ferric sulphate coagulation.

Alum is probably a little more efficient than ferric sulphate in coagulation at or near a neutral pH, but above pH 7.8 or below pH 6.4 ferric sulphate will be found more efficient.

If lime or other pH control measures are used in ferric sulphate coagulation it is generally considered best to apply such pH control ahead of the coagulant. Therefore in a straight coagulation plant employing pH control for corrosion control in the distribution system, the lime should be added to the water before the addition of the ferric sulphate. This is an advantage as smaller dosages of lime are thus employed and less lime is carried on to the filters to clog them. Ferric sulphate is also very responsive to break-point chlorination. It is generally found that break-point chlorination very definitely improves the coagulating ability of ferric sulphate and so if this type of treatment is used it should be ahead of the coagulant, if at all possible.

Color Removal, Taste and Odor Control

If the problem is that of color reduction, ferric sulphate may or may not be the answer. If using break-point chlorination for the color control, ferric sulphate will undoubtedly be a distinct advantage. If, however, coagulation takes place slightly below pH 7.0 and color control is by coagulation with alum, in most instances the alum will be found to be the cheapest coagulant to use. On the other hand if it is necessary to reduce the pH below 6.3 or 6.4 to remove the color by alum coagulation, ferric sulphate may again prove to be the most economical coagulant.

For taste and odor control by coagulation, ferric sulphate is generally very effective. Many tastes can be removed by coagulation provided that they are not first fixed by a definite change in pH. This permits lime to be added slightly ahead of the coagulant and thus maintain the raw water pH throughout the coagulating process. If this can be done, many tastes can be removed by coagulation which otherwise would be fixed if alum without lime were used and the coagulating pH thus lowered.

If iron is present in the raw water in any substantial quantity, the iron will normally react with the alum and interfere with coagulation. This same iron, however, in conjunction with a ferric coagulant will actually prove to be an aid to coagulation and dosages can be reduced to a minimum. This is an important fact to remember in areas where water plants are troubled with iron in the raw water.

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

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Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into areas by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by a barrel arrangement. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sits on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F	Pounds of Copper Sulphate Crystals ($CuSO_4 \cdot 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect: Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Urog'ena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. *Cyclotella* has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA

Organisms—Odor:	Copper Sulphate[1] Parts per million	Copper Sulphate[1] Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion			
Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria‡	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Glœocystis			
Offensive			
Hydrodictyon†	0.10	0.8	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50–1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Naist			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).

Los Angeles' Improved Dry-Feed Coppering Machines Used in Algae Control, Surface Applications Have Proved Economical and Effective. All Shallow Areas Are Reached Easily.

ACTIVATED CARBON TREATMENT OF AN OPEN RESERVOIR

By

HOWARD E. BAILEY
Consulting Engineer, Boston, Mass.

and

JAMES STUDLEY
Supt. of Water, Rockland, Mass.

ACTIVATED carbon was successfully applied to Great Sandy Bottom Pond as a treatment for taste and odors without subsequent filtration of the water. Nevertheless, none of the carbon reached consumers' taps. The treatment in conjunction with the use of copper sulphate was effective in eliminating taste and odors from the joint water supply serving 16,000 customers at a rate of about 1 million gallons per day in the towns of Abington and Rockland, Mass.

Great Sandy Bottom Pond

Great Sandy Bottom Pond, shown in the accompanying sketch, is the source of water supply for the two towns and lies in the Town of Pembroke, Mass., about 5 miles away. Tributary to the Pond is Little Sandy Pond, about one-half mile above, with a cranberry bog located on the stream between the two ponds. The area of Great Sandy Bottom Pond is approximately 108 acres and the capacity 350 million gallons at high water. At the time the treatment was carried out there were approximately 300 million gallons in the pond.

The maximum depth of the pond is 23 feet at a location several hundred feet north of the intake, where the depth of water over the 24-inch cast iron intake pipe is only 6 feet.

Early Troubles With Taste and Odors

The water supply system was established in 1885, and no trouble was experienced as of record until 1908. Again in 1927, tastes and odors were apparently aggravated by use (or misuse) of chlorine for a period of two or three years. In 1934 the taste and odor trouble was definitely attributed to the growth of algae. There were intermittent troubles between 1938 and 1944, when the quality of the water varied from "good to bad."

In the spring of 1944, tastes and odors which were described as "pig-pen" and "fishy" were recorded. A treatment of 7,000 lb. of copper suphate, or approximately 3 parts per million, made no change in the quality of the water, it is understood, but required removal of dead fish from the reservoir at a cost of $300. With the colder weather in December and the formation of ice, the tastes and odors disappeared.

In the spring of 1945, tastes and odors became prominent early in the year. In January staurastrum was present in 894 Areal Standard Units. In April 910 units of clathrocystis appeared in water samples from the pond, but in the tap water at the pumping station 2,310 units of the organism appeared.

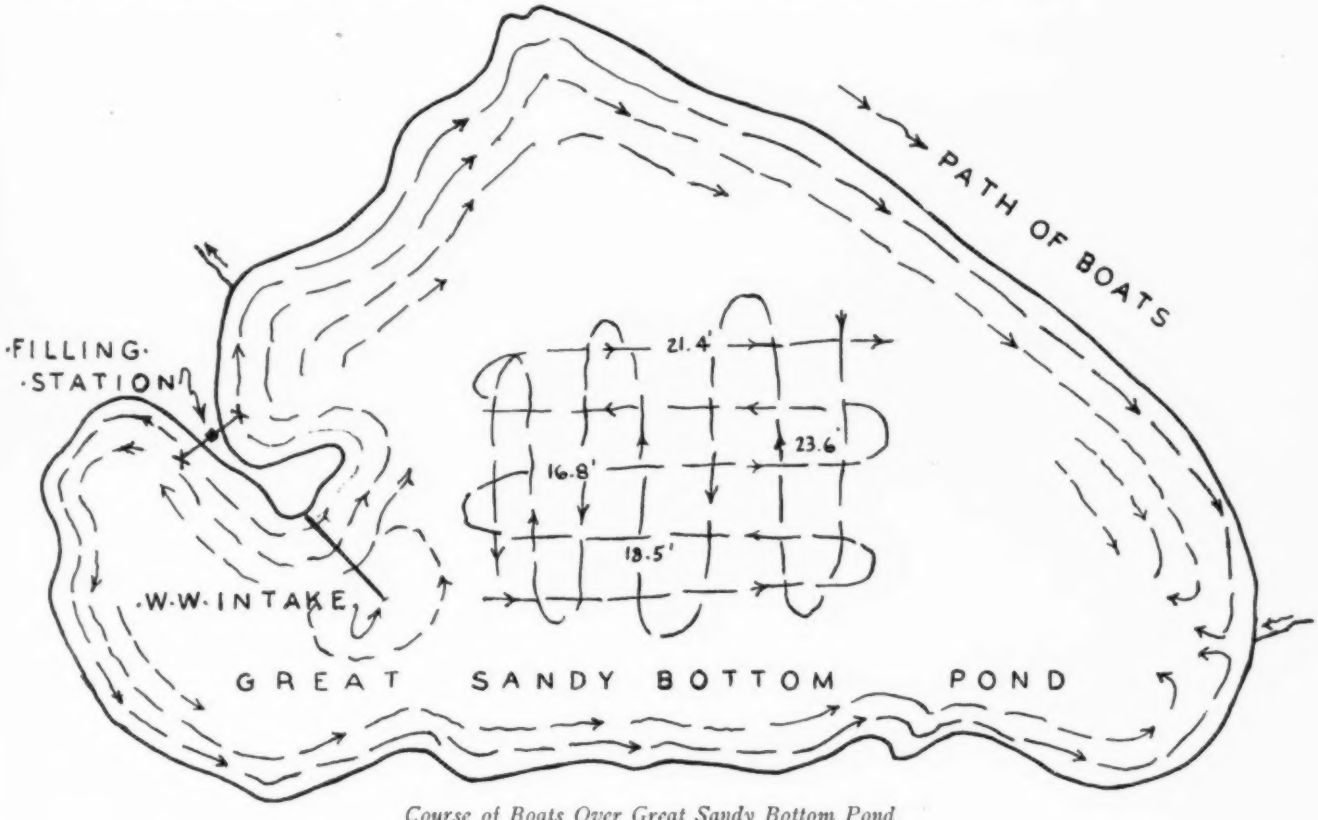
Treatment With Activated Carbon

Since the towns of Abington and Rockland had no other source of supply and the use of copper sulphate alone was not effective, the question arose as to whether activated carbon could be used to remove the taste and odors. The important question was: would the carbon stay in the pond and not require filtration before the water entered the distribution system? The customers apparently had no objection to the addition of "purifying charcoal," as they called it, to the water supply.

Upon advice from the carbon manufacturer, copper sulphate was first applied to the open reservoir, followed in a day or two by activated carbon. The chemicals were applied from two outboard motorboats following a route around the shore in the shallow water and the usual criss-cross pattern in the deeper areas—see accompanying sketch.

Dosages

On July 24, 1945, the calculated dosage of 0.6 ppm. of copper sulphate (1500 lb.) was applied to the pond by the usual method of dragging burlap bags filled with crystals behind an outboard motorboat. Early in the morning of July 25th, a breeze was blowing over the pond, accompanied by an unpleasant odor of fish. The turbidity of the water was high and water drawn from the tap in the pumping station was distinctly unpalatable. By 1 p.m., 1000 lb. of activated carbon had been introduced into the pond water, as later described, with the result that a reduction of the fishy odor was promptly observed. By 8 o'clock in the evening, a total of 3000 lb. of carbon had been distributed by outboard motors, corresponding with a dose of 1.25 parts per million. No carbon was distributed within 100 feet of the intake.



Course of Boats Over Great Sandy Bottom Pond
(Area, 108 Acres—Vol. 300 Mil. Gal.)

The Distributing Boat Taking on Its Load of Carbon Slurry

Results

On July 26th, the morning after the carbon treatment was completed, no taste, odor or turbidity was observed in the tap water at the pumping station, nor did any carbon appear in water samples drawn.

The intake screens in the pump well were covered with a gelatinous mass which was flecked with carbon particles but did not pass through the screen. During the first day after carbon treatment, the screens required washing at one-half hour intervals, where previously the screens were washed only once daily. The gelatinous clogging disappeared the next day and did not again appear when copper sulphate or carbon was used alone.

The turbidity decreased and disappeared within a few days.

A gelatinous mat, with a thickness of about ½ inch, covered the bottom of the pond. A microscopic analysis indicated that this was composed of amorphous matter and that no live algae were present.

The chlorine consumption (demand) dropped 3 to 4 pounds per million gallons.

Tastes and odors disappeared all over town one week later.

Sandy Bottom Pond six months later was again clear and the sand reappeared clean over the shallow areas of the pond.

Recurrence of Tastes and Odors

A recurrence of tastes and odors was expected and on August 6th 2000 lb. of activated carbon were added when a slight taste began to appear at the pumping station tap. On this and later occasions no attempt was made to stay clear of the vicinity of the 24-inch pipe intake in the distribution of carbon. The pond water remained without tastes and odors for remainder of the year. As a precaution, just before the ice formed, a dose of 0.4 ppm. of copper sulphate was added on November 16th, and 1.25 ppm. of carbon on November 17th and 18th. In the spring of 1946 a slight taste was evident and a repeat treatment of 900 lb. of copper sulphate and 3000 lb. of carbon was made on April 17th and 18th.

In the fall of 1946, when the cranberry bog was drained, the water entering the pond had a color of 180 and spiragyra was present in 2400 standard units. As a precaution, the above copper sulphate and carbon treatment was repeated on August 21st and 23d.

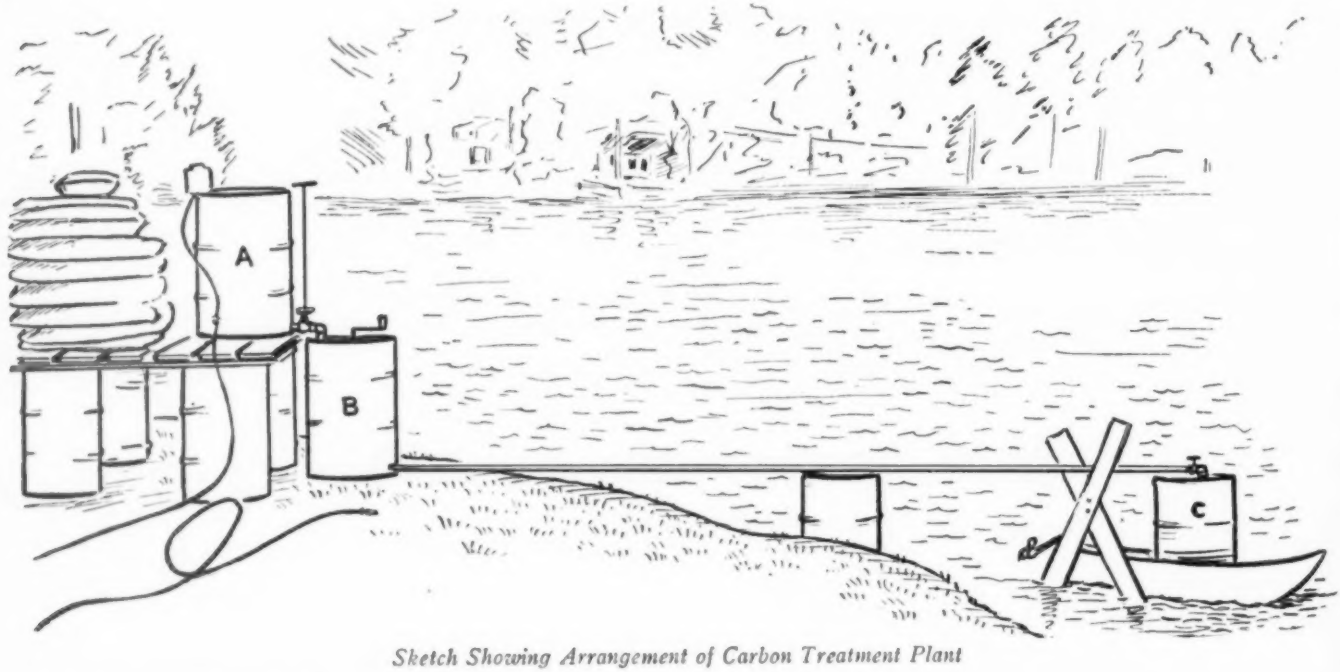
Method of Applying Carbon

The carbon was applied in a water suspension prepared at the filling station on the land and piped directly to the containers in the outboard motorboats. During the earlier treatments, the carbon was shoveled with scoops into a hand mixer contained in a steel oil barrel, but this method of hand mixing was abandoned in favor of the two-barrel electrical mixing plant shown in the accompanying sketches.

The carbon and water were introduced into the upper barrel which contained an ordinary electrically driven cellar drainer of the centrifugal pump type. The liquid was drawn through the bottom of the pump, mixed with the carbon in the impeller, and released at a good velocity on the periphery of the barrel through the pump discharge opening. A diagonal baffle attached to the side wall of the barrel broke up the rotary motion and prevented the contents of the barrel from rotating without mixing.

The second barrel, which contained the hand stirrer, was used to store the carbon slurry until the outboard motorboats were ready to receive it.

A pipe line from the storage barrel, supported on timber frames, carried the suspended carbon to the steel oil barrel container in the outboard motorboats. The distributing barrel in the boat was discharged through a 1-inch copper service pipe, carried up over the stern of the boat and terminating in the wash of the outboard motor propeller. A float indicator was provided to show the operator when the barrel was empty. The rate of discharge was observed as almost constant during the trip, due presumably to the constant vacuum created by the propeller wash.



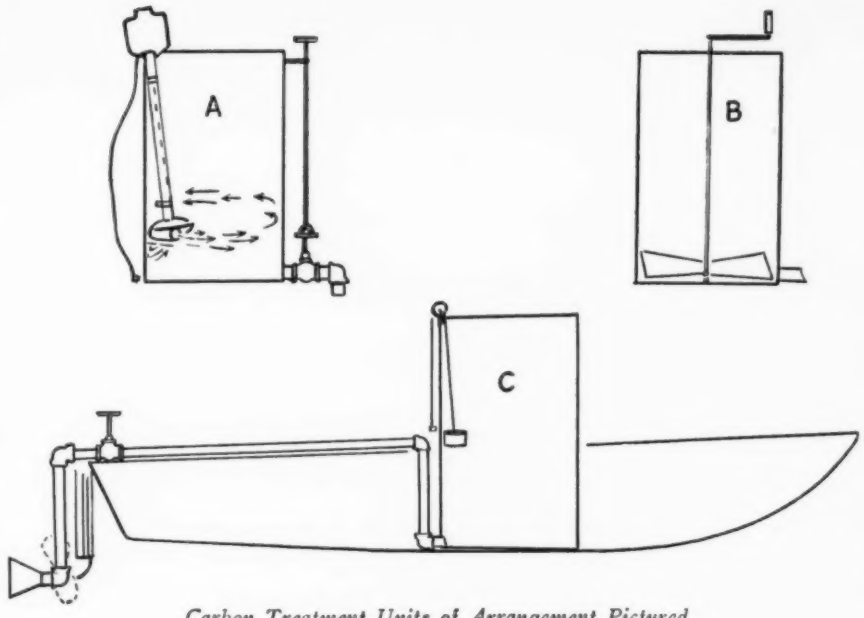
Sketch Showing Arrangement of Carbon Treatment Plant

Time and Expense

Each outboard motorboat distributed 75 lb. of carbon per 50-gallon barrel. The carbon could be observed in the wake of the boat in a well-distributed strip from 15 to 20 feet wide. Approximately 3 minutes were required to fill the boat's tank and 5 minutes to empty it. The speed of the boat was about 7 miles per hour, and 35 lb. of carbon were distributed approximately every 1500 feet. The time required to treat 300 million gallons of water with 3000 lb. of carbon was 10 hours for 4 men at a cost of $40.

Conclusion

Based on more than a year's treatment of Great Sandy Bottom Pond, it is possible to state that tastes and odors can be successfully combatted and removed on a 72-hour notice, and that the carbon will not appear in the distribution system, although no filtration of the water is provided. However, should specks of carbon have appeared at the customers' taps, no serious complaint was anticipated, since it had become generally known that "purifying charcoal" was being added to the reservoir in order to remove the far more objectionable tastes and odors.



Carbon Treatment Units of Arrangement Pictured
A—Mixing Tank Equipped with Electric Pump.
B—Slurry Storage Tank with Agitator.
C—Distributing Boat—Slurry Discharge to Propeller.

Block and Tackle Chart

Here is a chart that will be found useful for determining safe loads and proper loads in connection with ordinary block and tackle.

By laying a straight edge across the chart, as indicated by the dotted line, the pull necessary to lift any weight up to 200,000 pounds is immediately given in column B.

This chart takes into account the friction of the ropes and pulleys, which is less for a smaller number of ropes, although the pull on the lead line is decreased if a larger number of ropes are employed.

For example, what pull on the lead line is required to lift 20,000 pounds with five ropes?

Solution: The graduation corresponding to 5 in column A is connected by a straight line with that corresponding to 20,000 pounds in column C. The straight line intersects column B at approximately 4,700, which is the pull required.

The number of ropes supporting the load and used in column A is determined by counting the ropes leading to and from the moving block as illustrated by the sketches.

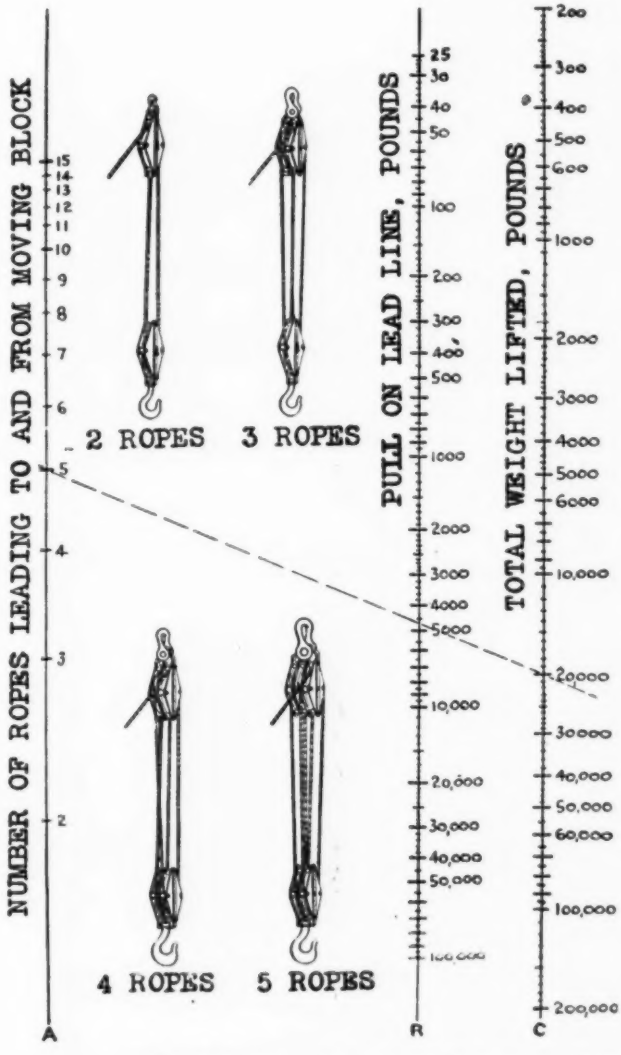
In arriving at the stress in the lead line, the common practice is to divide the weight of the load by the number of ropes supporting it, but this is not correct as it does not take into account the friction of the blocks or the rigidity and internal friction of the rope. The maximum stress when hoisting occurs in the lead line, since this besides taking a proportion of load on a single supporting rope also takes the accumulated friction of the blocks and rope in all the other parts of the tackle.

If, for example, a "seven rope" hoist is employed for raising a load of 35,000 pounds, according to the usual practice the stress in the lead line would be computed as 5,000 pounds, assuming that all parts pulled equally. This stress occurs, however, only in the becket line. The maximum stress is 6,325 pounds as determined by test. The chart gives that figure very closely, as will be observed.

Although this chart is based on figures that were determined for wire rope tackle, it is also applicable to ordinary manila rope.

It must be remembered, when buying a rope for use in a block and tackle, that the rope must be strong enough to resist the "maximum" pull, which is the pull in the *lead* line.

Contributed by W. F. Schaphorst, M. E., Newark, N. J.



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BEHAVIOR OF CHLORINE AS A WATER DISINFECTANT*

By GORDON M. FAIR, *Dean of Faculty of Eng.;* J. CARRELL MORRIS, *Asst. Prof. of San. Chemistry;* SHIH LU CHANG, *Asst. Prof. of San. Biology;* IRA WEIL and ROBERT P. BURDEN. *All of Grad. School of Eng., Harvard Univ., Cambridge, Mass.*

DURING the 40 years of its use as a disinfectant for municipal water supplies in America, chlorine has proved itself to be so powerful and versatile that it and certain of its compounds are almost the sole chemicals employed for this purpose today. Yet, despite the accumulation of a large amount of practical knowledge about its use, science is only now beginning to unravel the fundamental chemistry and biology of its disinfecting action. It is the purpose of this paper to describe the recent advances which are leading to an understanding of the behavior of chlorine as a water disinfectant and to indicate briefly those large areas of its behavior that still remain to be explored.

Chemistry of Chlorine in Water

The destruction of bacteria and other micro-organisms by a substance such as chlorine is essentially the result of a chemical reaction between the active agent and some vital substance necessary to the functioning of the organism. The characteristic action of the agent is dependent upon its chemistry and can be interpreted only when that chemistry is known. This statement is especially true for chlorine because of the wide variety of chemical reactions in which it participates.

General Properties

The element chlorine is the second member of the seventh column of the periodic table. Surrounding its nucleus, it has an outer shell of seven electrons, and, since an outer shell of eight electrons has great stability, atoms of chlorine show a strong tendency to acquire an extra electron to complete a shell of eight. The tendency to acquire electrons manifests itself as oxidizing activity. Correspondingly, elemental chlorine is a powerful oxidizing agent and in the great majority of its chemical reactions acts as an oxidizer. Other properties of elemental chlorine are of importance in connection with its technical use as a disinfectant. Because it may be liquefied at room temperature, at pressures of 5 to 10 atmospheres, it is relatively easy to transport and store in necessary quantities. Because of its considerable solubility in water—7,300 ppm. at 68° F. and 1 atmosphere—little difficulty is experienced in administering it to water in closely controlled amounts.

TABLE I

Ionization Constants for HOCl

Temperature °C.	Temperature °F.	K 10^{-8}
0	32	2.0
5	41	2.3
10	50	2.6
15	59	3.0
20	68	3.3
25	77	3.7

Hydrolysis

When chlorine is dissolved in water it undergoes a reaction of hydrolysis which may be represented by the chemical equation:

$$Cl_2 + H_2O \leftrightharpoons HOCl + H^+ + Cl^- \ldots (1)$$

In strong solutions, only a portion of the chlorine reacts in this way, but at the concentrations ordinarily employed for water disinfection the hydrolysis is virtually complete. Only if the pH of the water is below 3, or if chlorine concentrations in the neighborhood of 1,000 ppm. or more are employed, is any measurable quantity of Cl_2 present. In addition, it has been shown[3] that the rate of the reaction is so rapid that the hydrolysis is essentially complete within a very few seconds at ordinary temperatures.

Actually, therefore, it is incorrect to speak of disinfection by chlorine, for chlorine itself is not present for more than a fleeting instant under conditions of practical disinfection. However, the oxidizing capacity of the chlorine is retained in the hydrolysis product, HOCl, and it is with this hypochlorous acid that the major disinfecting action of chlorine solutions is associated.

Ionization of HOCl

Hypochlorous acid undergoes a further reaction with water, one of ionization, which may be represented by the equation:

$$HOCl \leftrightharpoons H^+ + OCl^- \ldots\ldots (2)$$

This is an essentially instantaneous, reversible process, so that one may write an equilibrium expression for it:

$$\frac{(H^+)\,(OCl^-)}{(HOCl)} = K \ldots\ldots (3)$$

In this expression the parentheses stand for activities (approximately equal to molar concentrations) of the enclosed substances, and K, called the ionization constant, depends only on the temperature. Values of K at various temperatures, compiled from a survey of experimental researches on the ionization of HOCl, are shown in Table I.

Rearrangement of the ionization constant equation gives:

$$\frac{(OCl^-)}{(HOCl)} = \frac{K}{(H^+)} \ldots\ldots (3a)$$

Hence the relative amounts of hypochlorous acid and hypochlorite ion present in a solution of "free chlorine"* are a function of the hydrogen ion activity, or pH. Analyses for "free chlorine" always determine the sum of the two species. Table II shows the percentage of the free chlorine present as undissociated HOCl at various pH values at 20° C. The table also records the amount of free chlorine required to give 1 ppm. of HOCl.

Since, as will be shown, the HOCl is the principal disinfectant in chlorine solutions, the efficiency of these solutions is a function of pH and varies in much the same way as the percentage of HOCl.

Hypochlorites

Hypochlorites, such as chloride of lime, calcium hypochlorite and bleach solution, establish this same ionization equilibrium in water. For example, when calcium hypochlorite is dissolved in water, it ionizes according to the equation:

$$Ca(OCl)_2 \rightarrow Ca^{++} + 2\,OCl^- \ldots (4)$$

The hypochlorite ions then combine with hydrogen ions from the water, as shown by the reaction:

$$H^+ + OCl^- \leftrightharpoons HOCl \ldots\ldots (2a)$$

This is just the reverse of the previous ionization equation (Eq. 2). The same equilibrium expression and constant hold, and the relative amounts of hypochlorous acid and hypochlorite ion at a given pH are exactly the same as for a chlorine solution. Hence, at the same pH, chlorine solutions and hypochlorite solutions must have the same disinfecting efficiencies. Reported differences in efficiency should be attributed either to experimental error or to failure to carry out the tests at the same pH value. The addition of chlorine tends to lower the initial pH value, whereas the addition of hypochlorite tends to raise it.

Chloramines*

The disinfecting action of chlorine solutions is further modified by the reaction of the hypochlorous acid with certain substances of frequent occurrence in natural waters. Ammonia and many organic amines combine with hypochlorous acid to give the chloramines. Again, as in the ionization of the hypochlorous acid, the oxidizing capacity of the chlorine is retained by the chloramines, so that starch-iodide and standard *o*-tolidine tests record chlorine combined with nitrogen as well as "free chlorine." Since the molecular nature of the chlorine has been modified, however, the disinfecting power is also changed.

The most important of the reactions of chlorine with nitrogen compounds is that of hypochlorous acid with ammonia itself. Although it is known that three compounds, monochloramine (NH_2Cl), dichloramine ($NHCl_2$), and nitrogen trichloride (NCl_3), may be formed, very little has been reported about the fundamental character of these reactions or about the interrelationships among them. Investigations initiated in the Laboratories of Sanitary Engineering at Harvard † on the ammonia-hypochlorous acid reactions have so far led to these conclusions:

1. The formation of the chloramines is a stepwise process for which the successive reactions

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O \ldots (5)$$
$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O \ldots (6)$$
$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \ldots (7)$$

may be written.

TABLE II

Percentage of Free Chlorine as HOCl

pH	HOCl per cent	Free Chlorine per ppm. HOCl ppm.
4	100	1.000
5	99.7	1.003
6	96.8	1.033
7	75.2	1.33
8	23.3	4.3
9	2.9	34
10	0.30	331
11	0.030	3,300

2. The rate of the first step, the formation of monochloramine, is very much dependent on the pH of the solution. The maximum rate occurs at a pH of 8.3 and decreases rapidly at higher and lower pH values. For example, at 25°C., with 0.8 ppm. of chlorine and 0.32 ppm. of ammonia-nitrogen, it requires about one minute for the reaction of 99 per cent of the chlorine, whereas at pH 5 it requires approximately 210 minutes and at pH 11 approximately 50 minutes. The reaction has been shown

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*See editorial note at end of article.

*See editorial note at end of article.

†The results quoted as issuing from these laboratories were obtained in researches supported in part by the Office of the Quartermaster General, in part by the Engineer Research and Development Laboratories and in part by the Wallace & Tiernan Research Fund in Chlorination.

to be bimolecular in accordance with the equation presented, and the variation in rate with pH can be calculated precisely on the basis of the solution equilibria that occur. The rate of the reaction also varies greatly with the temperature. Q_{10} values (*see* Table IV) of 2.0-2.5, depending on the pH, have been obtained.

3. The general statement that dichloramine is formed predominantly at low pH values (5-6.5) and monochloramine at high pH values (greater than 7.5) can be interpreted in terms of the equilibrium reaction:

$$2\,NH_2Cl + H^+ \leftrightarrows NH_4^+ + NHCl_2 \quad . . (8)$$

An excess of hydrogen ions should displace this reaction to the right, yielding greater amounts of dichloramine at lower pH values. This equation also predicts that the relative proportions of monochloramine and dichloramine should be affected not only by the pH, but also by the excess ammonia present. This has been confirmed by

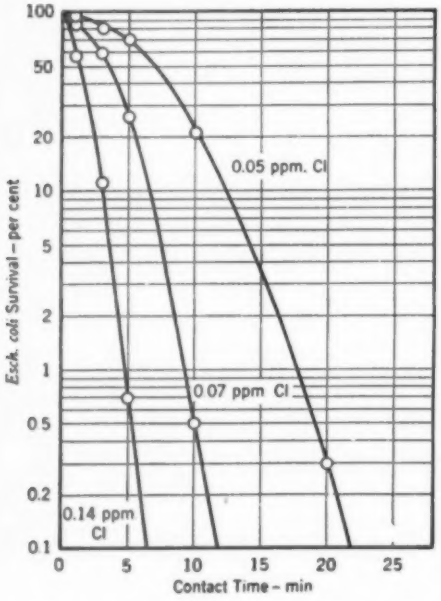

Fig. 1. Length of Survival of Esch. coli

spectrophotometric measurements, which also give a value of 6.7×10^8 for the equilibrium constant, where:

$$K_{eq} = \frac{(NH_4^+)\,(NHCl_2)}{(H^+)\,(NH_2Cl)^2} \quad . . . . (9)$$

Table III, calculated from this constant, shows the relative percentages of monochloramine and dichloramine at various pH values in solutions with a chlorine to ammonia-nitrogen weight ratio of 5:1.

Just as the disinfecting efficiency of solutions of free chlorine will vary with pH

TABLE III

Equilibrium Chloramine Distribution

pH	Chlorine as Dichloramine
	per cent
5	84
6	62
7	35
8	15
9	6

because of a change in the HOCl : OCl^- ratio, that of chloramine solutions will vary depending on the $NHCl_2$: NH_2Cl ratio. Consequently, any fundamental approach to the problem of disinfection by chlorine or its compounds must have as a background the types of basic chemical data that have been presented.

Chlorine Demand

Other reactions that lead to a loss of oxidizing chlorine also occur. Since HOCl is a strong oxidizing agent, its reaction with reducing substances is to be expected and results in the so-called "chlorine demand." In the reactions included under this heading, the chlorine atom manifests its great tendency to gain electrons and is thereby changed into the chloride ion or organic chloride. In this form, the chlorine atom no longer has oxidizing properties or disinfecting power. The substances responsible for the reduction of chlorine include inorganic Fe^{++}, Mn^{++}, NO_2^-, and H_2S, along with the greater part of the organic material in the water. The reaction of the inorganic substances is generally rapid and stoichiometric; that of the organic material is generally slow, and its extent depends upon the excess concentration of available chlorine present. Since the amount of organic material in natural waters is usually closely related to the color or stain, the organic chlorine demand can often be approximately estimated from the depth of color.

The occurrence of these reactions is a disadvantage to the use of chlorine as a disinfectant, for one must provide sufficient chlorine to take care of these side reactions before a reliable disinfecting action can be assured. Yet the occurrence of these side reactions stems from the same basic property that makes chlorine such a potent disinfectant—its high oxidizing activity—and the bad must therefore be accepted with the good in order to secure the activity.

Break-Point Reaction

Ammonia or organic amines may also exert chlorine demand in the "break-point reaction." This is another phenomenon which, like the formation of chloramines, is of great importance in disinfection but of which virtually none of the fundamental chemistry is known. Even the products of the reactions are uncertain. The active chlorine is probably reduced to chloride and the stoichiometry of the process indicates that ammonia-nitrogen is oxidized to the + 1 valence state, corresponding to N_2O, but this may result from a combination of products, such as N_2 and NO_2^-, rather than from any single product.

Experiments now in progress have so far established several points:

1. The rate of the reaction is strongly dependent on pH. A maximum rate is obtained at about pH 7.5 and decreases rapidly at high and low pH values.

2. One of the substances concerned in the break-point reactions is probably dichloramine.

3. The rate of the reaction is only slightly dependent on the temperature.

4. The rate of the reaction is very dependent on the total concentration of dissolved salts.

The complexities of the break-point reactions are so great that considerable additional work must be done before a consistent theoretical treatment can be achieved.

Biological Reactions of Chlorine

The way in which the remarkable disinfecting power of chlorine solutions is achieved has been the subject of speculation ever since the time of the first use of chlorine as a disinfectant. But the research necessary to provide an experimental foundation for theories of the mechanism of the disinfecting process was begun only a few years ago.

Mechanism of Cell Destruction

Early ideas that the action of chlorine was due to nascent oxygen or to a complete oxidative destruction of the organisms soon had to be abandoned because of the small concentrations of hypochlorous acid required and because of the failure of other oxidizing agents to work similarly. It was apparent that there was some selective attack on a vital and highly sensitive portion of the cell, but no one knew what this might be. The researches of Green [3] and his coworkers at Columbia University have now provided a satisfactory solution. According to Green, the death of the organism results from a chemical reaction of HOCl with an enzyme system in the cell that is essential for the metabolic functioning of the organism. The enzyme probably attacked is triosephosphate dehydrogenase, which is found in practically all cells and is essential for the utilization of glucose. Attack on other enzymes is not excluded,

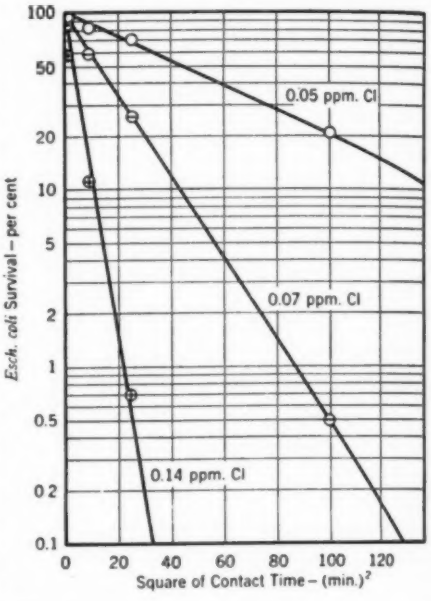

Fig. 2. Length of Survival of Esch. coli

but triosephosphate dehydrogenase was found to be especially sensitive to oxidizing chlorine. The reaction was presumed to take place with —SH groups of the enzyme, which are oxidized by the chlorine. This theory provides an explanation of the extreme sensitivity of organisms to chlorine, since enzymes are present in cells in very minute quantities and yet are absolutely essential as catalysts for metabolic activity.

These ideas do not, however, furnish a complete answer to the problem of chlorine disinfection, for when the enzymes are removed from the cell, they are equally susceptible to attack by many oxidizing agents, such as H_2O_2 and $KMnO_4$, whereas chlorine is markedly superior in its attack on intact cells. The difference can be explained on the basis that, for the intact cell, not only the ability of the reagent to react with the enzyme is of concern, but also its ability to gain access to the enzyme by penetrating through the cell wall. Laboratory studies indicate that it is this latter factor—the rate of diffusion of the active agent through the cell wall—which largely determines the rate of disinfection and the relative efficiency of various disinfecting materials. From this point of view, it is not primarily the strong oxidizing power of HOCl that makes it a superior disinfectant, though that is essen-

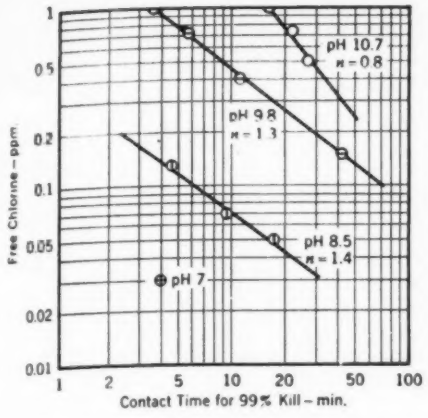

Fig. 3. Free Chlorine Requirements

tial, but rather its small molecular size and electrical neutrality. These allow it to pass readily through the cell membrane. Confirmation of this hypothesis must be sought in more extensive fundamental studies of the rate of kill of organisms by various disinfecting agents and of variations in the rate with changing conditions.

Disinfection Efficiency

The principal factors that affect the efficiency of destruction of a particular species of organisms are: time of contact, concentration of organisms, concentration of disinfectant, temperature, and nature of the disinfectant. Dynamic studies of all these elements are essential for a thorough understanding of the disinfection process. Up to the present, the only thorough studies of these factors as they relate to the action of chlorine solutions on bacteria have been made by Butterfield *et al*[2] and by Wattie and Butterfield [4, 5]. Even their admirable results, which form the basis for the following discussion, are not entirely satisfactory for theoretical calculations, however, and it is hoped that the extreme difficulty of the experiments that must be conducted will not prevent further studies of this type with theoretical objectives in mind.

Time of contact. The effect of contact time on the killing of organisms has generally been expressed in terms of Chick's Law, which may be written in the form:

$$\log \frac{N}{N_0} = -kt \ldots\ldots (10)$$

Here N/N_0 is the fraction of the original number of organisms remaining at time t and k is a proportionality constant. A plot of log N/N_0 against t for various times of contact should give a straight line. Figure 1, prepared from the data of Butterfield *et al.* (3) for the destruction of *Esch. coli* by chlorine at pH 8.5 and 2°—5°C., shows that Chick's Law does not hold for disinfection by chlorine. Similar curves are obtained at other pH values, at other temperatures, for other species of bacteria * and for chloramines as well as free chlorine.

Linear relations are created for the results in Fig. 1 if log N/N_0 is plotted against t^2 rather than t. This is shown in Fig. 2. A relation of this character can be explained in two ways: (1) as a combination of slow diffusion through the cell wall and a rate of killing dependent upon the concentration of disinfecting material inside the cell; (2) on the assumption that there are three to four active centers in the organism and that the organism is not dead until all of these centers have been destroyed[6]. Further studies are needed to clarify these points.

Concentration of organisms. Virtually nothing is known about the effect of concentration of bacteria on the rate of disinfection. Butterfield[3] refers to one series of experiments with an initial concentration of organisms tenfold smaller than that normally employed and states that no significant difference in the percentage destroyed at various times was observed. This is the result one would intuitively expect, but it should be checked more extensively.

TABLE IV

Temperature Dependence of Disinfecting Action of Aqueous Chlorine and Chloramines

	pH	E cal.	Q_{10}
Aqueous Chlorine	7.0	8,200	1.65
	8.5	6,400	1.42
	9.8	12,000	2.13
	10.7	15,000	2.50
Chloramines	7.0	12,000	2.08
	8.5	14,000	2.28
	9.5	20,000	3.35

Concentration of disinfectant. Changes in disinfection efficiency with concentration of the disinfectant can be expressed mathematically by the equation:

$$C^n t = k \ldots\ldots\ldots (11),$$

In this equation, C represents the concentration of disinfectant, t represents the time required for a constant percentage of the organisms to be destroyed and n is a constant which may be called the concentration exponent. High values of n indicate that the disinfectant decreases rapidly in effectiveness as it is diluted; with low values of n, the time of contact becomes more important than the dosage.

Values of n are determined by plotting log C against log t and measuring the slope of the lines. A series of such plots, using the times required for 99 per cent of the bacteria to be killed, is shown in Fig. 3 for free chlorine solutions. A similar series for chloramines appears in Fig. 4, except that the times are for 50 per cent kills of the bacteria, sufficient data for 99 per cent kills not being available. No theoretical

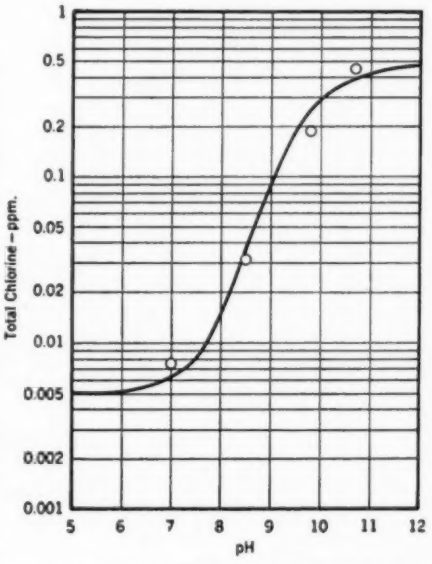

Fig. 5. Relative Disinfecting Efficiency of HOCl and OCl⁻

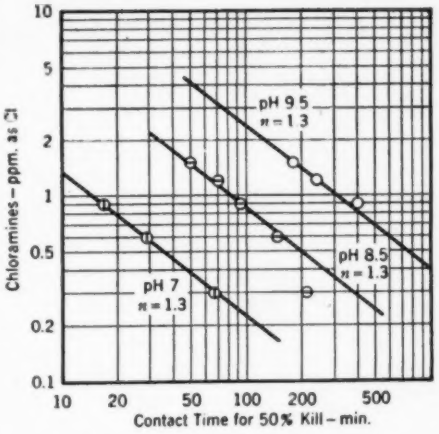

Fig. 4. Chloramine Requirements

significance can be attached to the values of n obtained; the equation itself is without theoretical foundation and is just an expression for the correlation of data.

Temperature of disinfection. If either the rate of diffusion through the cell wall or the rate of reaction with an enzyme determines the rate of disinfection, its variation with temperature is best expressed by the equation:

$$\log \frac{t_1}{t_2} = \frac{E(T_2 - T_1)}{4.575 T_1 T_2} \ldots\ldots (12)$$

The symbols T_2 and T_1 stand for two temperatures (in degrees Kelvin) between which the rates are being compared; t_1 and t_2 are the times required for equal percentages of kill at a fixed concentration of disinfectant; and E, called the activation energy, is a constant characteristic of the reaction. When $T_2 - T_1 = 10$, the ratio t_1/t_2 is frequently called Q_{10}. For studies in the vicinity of 20° C., Q_{10} is approximately related to E by the formula:

$$\log Q_{10} = \frac{E}{39{,}000} \ldots\ldots (13)$$

Values of E and Q_{10} for the destruction of *Esch. coli* by chlorine and chloramines, computed from the work of Butterfield *et al.* [3], appear in Table IV.

Nature of disinfectant. Fig. 3 shows that the disinfection efficiency of chlorine decreases markedly with an increase in pH. This can be accounted for by postulating that HOCl is a far stronger disinfectant than OCl^-, since the percentage of the free chlorine in the solution in the form of HOCl decreases very rapidly with increasing pH, as shown previously. By assuming an additive disinfecting efficiency for HOCl and OCl^-, one can calculate a theoretical curve for the total amount of free chlorine required to produce a given percentage of kill in a specified time at various pH values. The equation employed is:

$$R = A \frac{1 + \frac{K}{(H^+)}}{1 + B\frac{K}{(H^+)}} \ldots\ldots (14)$$

in which R is the required total chlorine, A is the concentration of HOCl alone required to produce the desired percentage of kill and B is the ratio of the efficiency of OCl^- ion to that of HOCl. In Fig. 5, the observed concentrations of aqueous chlorine required to kill 99 per cent of *Esch. coli* in 30 minutes at 2°—5°C. have been plotted against the pH and fitted with a theoretical curve whose equation, corresponding to Eq. 14, is:

$$R = 0.005 \frac{1 + \frac{2.2 \times 10^{-8}}{(H^+)}}{1 + \frac{0.012 \times 2.2 \times 10^{-8}}{(H^+)}}$$

*There are some exceptions to the general failure to obey Chick's Law. For example, destruction of *Shigella dysenteriae* by chloramines below pH 8 follows the law quite closely. Exploration of the reasons for this might yield information of considerable value.

The value of B used, 0.012, indicates that the OCl^- ion possesses about 1/80 of the disinfecting efficiency of HOCl under the stated conditions.

Since Fig. 5 shows that at pH 7 and 8.5 essentially the whole disinfecting action is due to HOCl, whereas at pH 10.7 it is chiefly due to OCl^-, the characteristic constants obtained at these pH values may be identified with the disinfecting process for the corresponding species. Thus the values $n = 1.4$ and $E = 7{,}000$ calories are connected with disinfection by HOCl, while the values $n = 0.8$ and $E = 15{,}000$ cal. refer to the reaction of OCl^-. It is of interest to note that the value of $E = 7{,}000$ for the action of HOCl is in the range of activation energies for diffusion, whereas the value of $E = 15{,}000$ for the action of OCl^- is more characteristic of a chemical reaction. Perhaps, therefore, the rate-determining processes are different for these two substances.

A plot similar to that in Fig. 5 might be made for the chloramines, but the data are so scanty, and reliable values for the chloramine equilibria are so recent, that this has not yet been done. However, the manner in which the disinfecting efficiency of chloramine solutions decreases with increasing pH (*see* Fig. 4) indicates qualitatively that NH_2Cl, which is favored at the high pH values, is less efficient disinfectant than $NHCl_2$. In addition, a tentative quantitative evaluation of the rate of change with pH suggests that the entire disinfecting action in the solutions studied may have been due to $NHCl_2$ and that NH_2Cl may be so weak a disinfectant that its influence was not felt.

Effects on Other Organisms

The biological reactions of chlorine have been illustrated in this paper for but a single organism, *Esch. coli*, a "type organism of water contamination" rather than a water-borne pathogen. The pathogenic organisms that should be considered in connection with water chlorination include: (1) the enteric vegetative bacteria (*Eberthella, Shigella, Salmonella* and *Vibrio* species); (2) intestinal protozoa, the most important representative of which is *Entameba histolytica;* (3) worms, such as the blood flukes (*Schistosoma* species); and (4) viruses—for example, the virus of infectious hepatitis.

Each of these groups of organisms differs in its reaction to chlorine, and there is considerable variation, too, in the behavior of the different species within the individual groups. There is some evidence, furthermore, that the comparative reaction of different organisms to one form of chlorine is not necessarily maintained relative to other forms.

Much research will have to be done before the pattern of the biological reactions of significant organisms is fully established. Of the four groups of pathogenic organisms, the enteric bacteria are most easily destroyed by ordinary chlorination procedures, whereas the cysts of *E. histolytica* appear to be the most resistant[7].

Editor's Note

The A.W.W.A. committee which has prepared the chapter on "Chlorination and Other Disinfection Practices" for the forthcoming Manual of Water Quality and Treatment has set up the terms "free available chlorine residual" and "combined available chlorine residual" to replace the terms "free chlorine" and "chloramine," respectively. The committee considers that free available chlorine may exist as elemental chlorine, hypochlorous acid (HOCl) or hypochlorite ion (OCl^-)—or as hypochlorous acid and either of the other two forms—depending on the pH of the solution. The concept of combined available chlorine envisages the presence of ammonia or other nitrogenous compounds which have the capacity to combine with chlorine (or hypochlorous acid) and thus modify its rate of bactericidal action.

Based on the foregoing distinction, the committee has suggested that chlorination practices be classified as free residual chlorination and combined residual chlorination.

Conclusion

A remarkable record of accomplishment has been established by chlorination during the 40 years since it was first applied to a public water supply in America. Pride in the reduction of water-borne typhoid fever and dysentery, however, must not obscure the need for intensifying researches into the chemistry and biology of water chlorination. The cost of water disinfection, to be sure, is negligible in terms of the savings that it has effected and will continue to effect in the prevention of sickness, suffering and death. The total annual expenditure for chlorine as a water disinfectant and its significance in the prevention of water-borne disease are sufficiently large, however, to warrant the cost of all the investigations that must yet be entered upon to acquire the necessary understanding of this—surely the most important—water works chemical. No industry can long afford the luxury of ignorance, even though it is tempered by accomplishment; neither can a profession that, like the water works profession, is so clearly devoted to the protection and promotion of the public health.

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TEN PACKING "DON'TS" WORTH HEEDING

It is well known that "don'ts" are often more effective than "do's", so here are some suggestions and warnings arranged as "don'ts" that are based on many years of practical experience. They will be found useful in connection with the selection and installation of packings. To follow them may mean freedom from trouble that would occur when even the best obtainable packing is improperly installed.

1—DON'T fail to make clear what the packing is to pack. In other words, with what will the packing make contact?

2—DON'T guess at a size, diameter, width or height when ordering packings. Many failures have resulted from small errors in dimensions.

3—DON'T allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall; 1/16 to 3/32 inch on each side, depending on size of packing, is usually recommended.

4—DON'T doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.

5—DON'T apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean so sediment will not collect in cylinders and wear the packing.

6—DON'T apply cup packings to end of plunger which is badly worn; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.

7—DON'T apply "U" packings where plungers are worn without reinforcing under heel with leather cushion rings.

8—DON'T look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.

9—DON'T allow water to corrode cylinder walls, plungers or rods. Use an anti-rust agent that will prevent this and that will act as an effective lubricant.

10—DON'T squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set glands up to point where "U" packings are free to function properly.

———

Contributed by W. F. Schaphorst, M.E., Newark, N. J.

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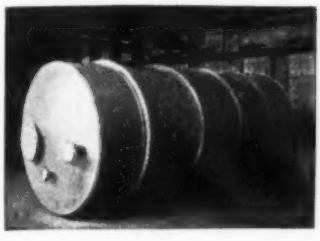

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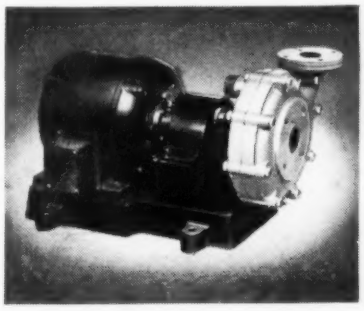

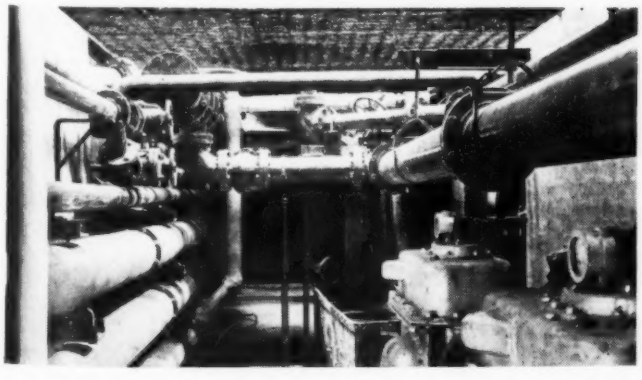

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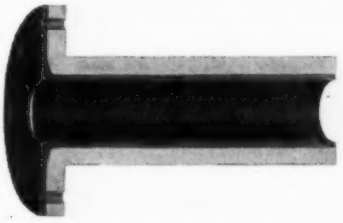

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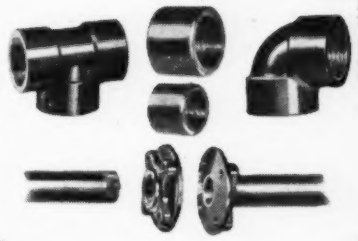

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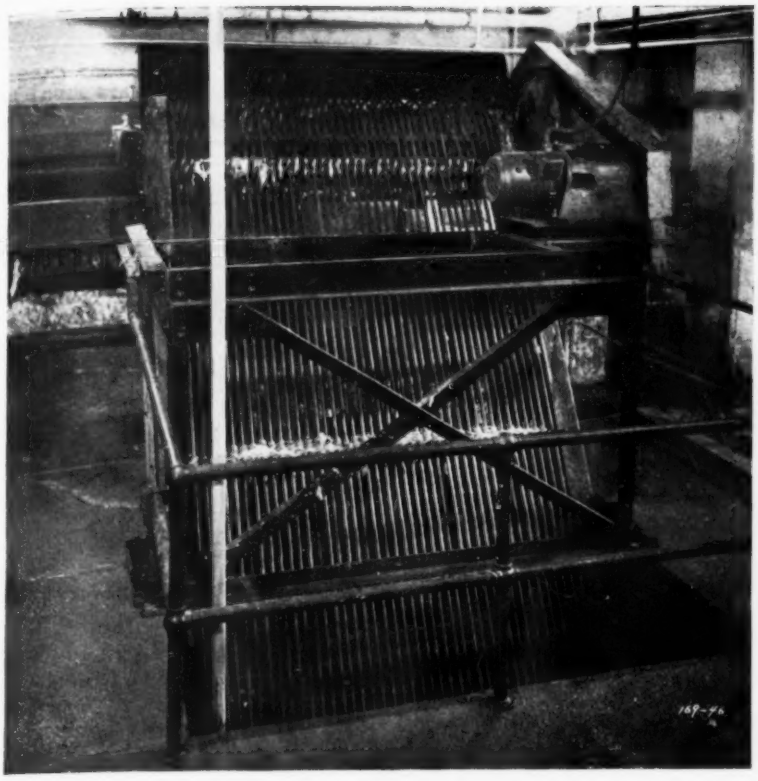

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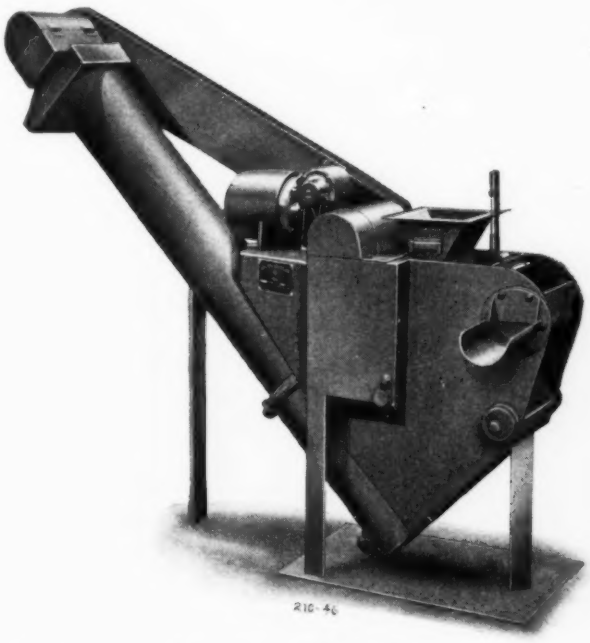

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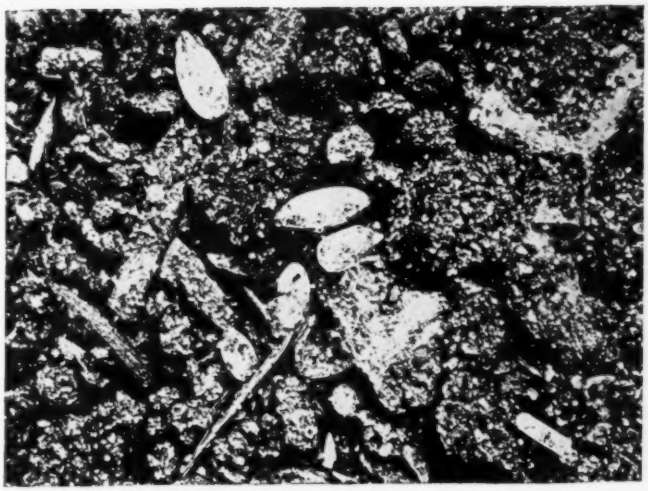

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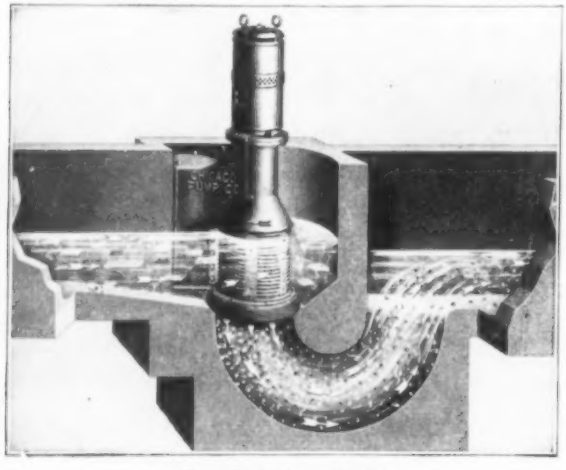

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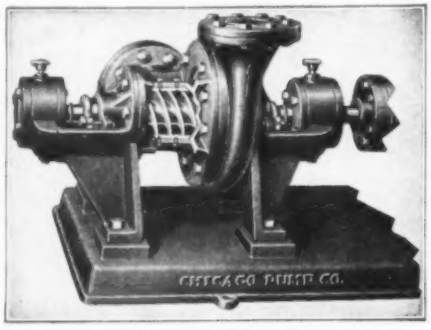

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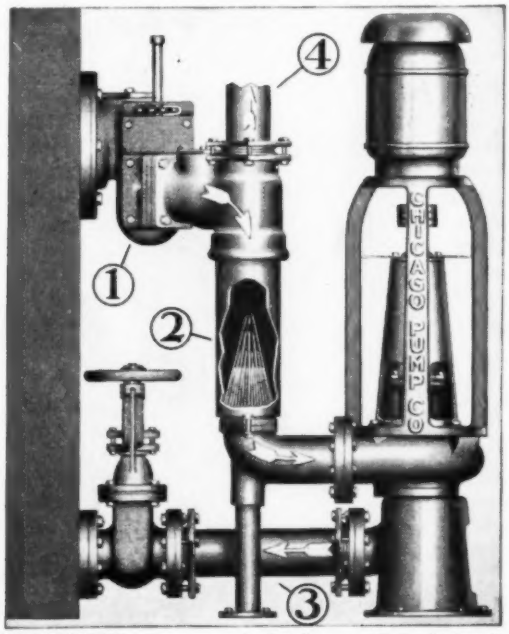
Ingenious automatic features of Chicago "Pakage" Plants simplify operation and assure successful performance. Aeration and clarification are performed in a single tank with positive, automatic sludge control. One sludge setting covers a wide range of sewage flows and strengths.

Initial cost of "Pakage" plants is low and they are inexpensive to operate. Since 1934 over 100 of these plants have been installed and are successfully operating.



The FLUSH-KLEEN pump cannot clog because it is designed so that no solids can reach the impeller. Sewage flows through inlet pipe (1). Solids are retained on screen (2). (3) Strained sewage flows through idle pump to wetwell. As pump switches on, Checkvalve closes, sewage on strainer is backwashed and carried off through outlet pipe (4).

FINANCING SEWERAGE IMPROVEMENTS

By ROBIE L. MITCHELL

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Mitchell and Pershing, New York, N.Y.

The author of this article, with a background of experience in developing plans for financing sewerage improvements, drew up and later successfully defended the Sewer Revenue Ordinance of the City of Miami before the Florida Supreme Court.

In this important case the favorable decision won by Mr. Mitchell from Florida's Supreme Court not only established the constitutionality of the Sewer Service Charge method of financing sewerage improvements in the state of Florida, but also established a precedent of considerable importance in future cases of like nature in all parts of the country.

ONE of the most pressing problems in many urban communities is the disposal of sewage and industrial wastes. The pollution of our rivers, harbors and inland and coastal waters into which raw sewage and industrial wastes flow directly or are being pumped has not only impaired or destroyed their value for fishing and recreational purposes, but has already become a serious menace to the health of the people and this menace is increasing more and more with the rapid increase in our urban population. Some of our cities pump their water, including the water which is used in their homes, from rivers which are polluted upstream by the raw sewage of another city or by chemicals and wastes from some mill or factory. It would take a lot of persuasion to make me believe that any city or private corporation has the right so to pollute the rivers and harbors which God has given to all the people of this country.

What are we going to do about it?

For one thing, we can require private industry to clean up its own mess by treating it before dumping it into a river, or by running it through a city's sewage treatment plant and paying for the service.

Financing the Big Problem

Our big problem comes in financing the construction of the sewage treatment plant.

In the past the construction of sanitary sewers and sewage disposal systems has been financed for the most part by the issuance of general obligation bonds supported by taxes or by taxes and special assessments. In many cities special assessments for all or a portion of the cost of sanitary sewers have been levied upon the property abutting upon the improvement, whether such property is improved or unimproved. The balance of the cost and the cost of intercepting sewers, force mains, pumping stations and outlets and sewage treatment plants in the cases where they have them, have been borne by the taxpayers at large of the cities. As it is extremely difficult, if not impossible, to sell bonds payable solely from special assessments, the cities would issue their general obligation bonds payable from taxes, the amount of the taxes in each year being reduced by the amount of special assessment collections.

But constitutional limitations and restrictions on the issuance of bonds or the incurring of debt have caused us in recent years to consider the possibility and the feasibility of financing the construction of sewage disposal systems by the issuance of revenue bonds, the interest on which is payable solely from the proceeds of sewer service charges (sometimes referred to as sewer rental) to be imposed on those whose sewage is disposed of or treated by the system.

Legal Questions Involved

I was first called upon to draft legislation for this type of financing 17 years ago. We then had very few court decisions to help us as only a few cities had attempted to impose a charge for their sewers. We have been confronted with these legal questions:

1—What are sewer service charges? Are they related to the taxing power, or are they to be classified as special assessments based on benefits? If the former, must the proposed bonds be authorized at an election or must they be included in computing constitutional or statutory debt limits? If they are to be treated as special assessments, should not provision be made for a public hearing after proper notice? Or are they to be treated merely as charges for services rendered?

2—On what factors should the sewer charges be based?

3—How shall the collection of delinquent charges be enforced?

In 1945 I drafted legislative acts to authorize several cities to construct sanitary sewers and sewage disposal systems, to impose sewer service charges and to finance such construction by the issuance of sewer revenue bonds payable solely from such sewer service charges. For fear that the courts might possibly hold that the sewer service charges to be imposed under these special acts should be treated as special assessments, I provided in the acts for a public hearing on these service charges in substantially the same manner as in the case of special assessments.

I then prepared the ordinance for sewer revenue bonds in two of these cities. The conditions in the two cities are not the same. In one about ¼ of the area, in which about ½ of the population live, had sewers, through which raw sewage flowed or was pumped into a bay in the city's front yard. These sewers had been paid for by general obligation bonds of the city, payable from taxes on all taxable property in the city and additionally secured by the proceeds of special assessments levied on the property abutting on the sewers. The new project involved the laying of additional sewers in the remaining populated sections of the city and the construction of a sewage disposal plant to treat and dispose of the sewage from the entire city. In setting up the financing program it was felt that it would not be equitable to impose the same charge on property which had already paid special assessments as on the property to be served by the new sewers. So provision was made for companion bond issues, one to cover the cost of the new sewer lines (collection system) and the other to cover the cost of the sewage disposal system, including the *intercepting* sewers, force mains, pumping stations, the treatment plant, etc. The first issue consisted of general obligation bonds payable from unlimited ad valorem taxes and additionally secured by special assessments (for about 60 per cent of the cost) on abutting property. This would place the property owners getting the new sewers on substantially the same basis as those who already had sewers and who had paid special assessments for a part of the cost of their sewers. The second issue consisted of unsecured sewer revenue bonds, payable solely from sewer service charges based on water consumption by the sewer user.

This plan of financing would place some burden on the owners of unimproved property in the new area, special assessments for the new sewer lines in front of such property and a tax to pay a part of the first issue of bonds. The second issue of bonds would be payable from equitable sewer service charges based on extent of use of the sewer in both the old and the new areas.

No One Plan Will Fit Every Case

The consulting engineers suggested that some charge be imposed on all unimproved property in the city in the nature of a "readiness to serve" charge on account of the fact that the construction of the system could be shown of benefit to all property in the city, whether improved or unimproved. But from the decisions of the courts up to that time, including the decisions of the Supreme Court of Pennsylvania in two Philadelphia cases, I feared that any such "readiness to serve" charge would be treated as an exercise of the taxing power, requiring an election on the issuance of the proposed bonds and also the inclusion of such bonds in computing the charter debt limit of the city.

In another city we now propose to include in the sewer revenue financing the cost of the sewer lines in the presently unsewered area and impose an "adjusted" service charge on the people in that area instead of a special assessment. It would appear from two decisions of the Supreme Court of that state that, if the proceeds of special assessments should be pledged to the bonds, it would be necessary to hold an election on the question of issuing the bonds. In another city, where the present sewers are entirely inadequate, many of them must be reconstructed and new sewers as well as a sewage disposal system constructed, the authorizing ordinance which was adopted last month makes a uniform sewer service charge on all users because of the extensive reconstruction required to place the existing sewers in good condition.

I have mentioned these different situations to show that there is *no one plan of financing which will fit every case.* The financing plan for each situation may have to be a tailor-made job and the working out or the setting up of each plan will involve a considerable amount of work and the closest cooperation on the part of the governing authority and its consulting engineers, bankers and lawyers.

Referring now to the three legal questions which have confronted us:

1—What are sewer service charges?

2—On what factors should the sewer service charges be based?

3—How shall the collection of delinquent charges be enforced?

What Are Sewer Service Charges?

In my opinion these questions are closely related and all of them have been convincingly answered by the Supreme Court of Florida in its opinion affirming the decree of the lower court validating a proposed issue of Sewer Revenue Bonds of the City of Miami, reported in 157 Fla. 726, 27 So. (2d) 118, and printed in full in *The Daily Bond Buyer* of August 5, 1946. I feel that this opinion is one of the greatest contributions in the field of municipal finance of any of the court decisions in recent years and that it will be relied on by the courts in other states as the leading decision on the subject.

Prior to preparing the brief in the Miami case, I read every decision on the subject which I could find and a great many articles, some prepared by leading engineers. Analyzing all this and drawing on my very limited knowledge of irrigation law in Montana, where I was engaged in general practice for a few years before getting into the municipal work in the Attorney General's office, I reached the conclusion that, fundamentally, sewer service charges are identical with water rates, that in reality they should be considered to be the second half of the water bill. In paying the water bill we do not pay for the water *itself* as we do for a ton of coal (or a bushel of potatoes) but for its *use*. As stated in my Florida brief,

> "In a modern city a waterworks system would be utterly useless without a system for the disposal of sewage. The service rendered by a waterworks system is only half of the complete service required. Through the waterworks system water which has been purified in accordance with standards prescribed by the proper health authorities is brought to the premises of the consumer for use. Through the sewer system the identical water, carrying the pollution resulting from its use in bathtubs, showers, sinks, washtubs and toilets, is taken from the premises and disposed of in accordance with standards prescribed by the same health authorities. For the service rendered by the waterworks system water rates or charges are imposed. For the service rendered by the sewer system sewer service rates or charges are imposed. The consumer does not pay for the water in either case but for its use, for the service rendered."

I relied to a great extent on recent decisions in New Hampshire, Pennsylvania and Arkansas. The Supreme Court of New Hampshire in Opinion of Justices (1944) 93 N. H. 478, 39 Atl. (2d) 765, had said "sewer rents imposed by the city of Concord are neither taxes nor assessments for a local benefit but, like water rates * * * are charges made for a service rendered." It was contended by the Attorney General that the principle of law which exempts the property of the State from taxation under general statutory provisions also precludes the imposition of a special assessment for improvements upon such property, but it was held that the charges of the city for sewer service are in no sense special assessments.

The City of Philadelphia was authorized by statute to charge and collect "annual rentals for the use of sewers, sewage systems and sewage treatment works," and such charges "shall be apportioned equitably among the properties served by the said sewer, sewage system, or sewage treatment works." In two decisions of the Court it was held that the ordinances passed by the City of Philadelphia did not comply with the statute because they imposed taxes and not charges for the use of the sewers. In the first case (In re Petition of the City of Philadelphia (1940) 340 Pa. 17, 16 Atl. (2d) 32) the ordinance was held invalid because the charge was made applicable not only to properties actually connected with and accommodated by the sewer system but also to vacant lots and properties not connected with the sewer system. In the second case (In re City of Philadelphia (1941) 343 Pa. 47, 21 Atl. (2d) 876) the rate imposed by the ordinance was a combination of two factors: (1) three mills upon each dollar of assessed valuation, and (2) 25 per cent of the water service charge, or water rent. The sewer rental rate based on assessed valuation of properties actually using the sewer system was held invalid as a tax measured by the value of properties served without relation to the use of the sewers.

In the third ordinance, which was sustained in Gericke v. City of Philadelphia (1945) 353 Pa. 60, 44 Atl. (2d) 233, the charge was "based upon the water consumption of the property served as measured by the charges for water supplied (water service) for the then current calendar year."

Only a short time before filing the brief, the Supreme Court of Arkansas in City of Harrison v. Braswell (1946) 209 Ark. 1094, 194 S.W. (2d) 12, sustained an issue of water and sewer revenue bonds of the City, payable solely from revenues of the municipal waterworks and sewer systems, saying:

> "A sanitary sewer system without water would be a total loss, and a water system without a sanitary sewer system would be impractical, if not entirely useless. So each complements or supplements the other."

In its decision in the Miami case the Florida Supreme Court held that the imposition of fees for the use of the sewage disposal system is not an exercise of the taxing power or the levy of a special assessment, saying:

> "A sewer system is complementary to a water system. A sewer system would be of no value without a water system and a water system would be entirely incomplete without a sewer system. So the principles of law which would apply to one system must likewise apply to the other."

Basis of Charges

Referring to the second question, the sewer service charges in the Miami ordinance were a certain percentage of the water bill, which in turn is based upon the quantity of water consumed as determined by meter measurement. This method appears to be the most equitable and was sustained by the Florida Supreme Court.

Collection of Delinquent Charges

As authorized by a provision we incorporated in the special legislative act, the Miami ordinance provided that the amount of the sewer service charges shall be actually included in the water bill, but each bill showing separately the amount of the sewer service charges and the amount of the bill for water, and that if the sewer service charges are not paid within thirty days from the rendition of the bill, the City shall discontinue furnishing water to the premises and shall disconnect the same from the waterworks system of the City.

In approving this method for the collection of delinquent sewer service charges, the Florida Supreme Court said:

> "Question Three is closely related to Question Two because it challenges the method provided for the enforcement of the charges for the use of the sewage disposal system * * *.
>
> "It is uniformly held that the City may cut off the water being furnished by the City to a consumer when such consumer fails to pay the water bill. * * *
>
> "It appears to us that if no constitutional rights of the owner or occupant of premises are violated by shutting off the water for non-payment of the water bill, no such right will be violated by shutting off the water for non-payment of the bill for use of the sewage disposal system, the two services being so interlocked that neither can be effective without the other."

In other words it becomes a case of "New and Used Water" as one water and sewage works manager has so aptly put it.

Forcing Connections with Sewer System

In cases where the premises of a substantial percentage of the population are using septic tanks and are not connected with the sewer system of the City, we have another problem. Is it lawful to include in the ordinance authorizing sewer revenue bonds a provision requiring the owners of such premises to connect with the sewer system and cease using their septic tanks?

If the construction of the sewage disposal system is to be financed by revenue bonds, payable solely from sewer service charges, a requirement to connect with the sewer system or else pay the charge in any event may be important. But if the construction is to be financed by general obligation bonds or if the statute authorizes, and the constitution of the state permits, the imposition of a readiness to serve charge on such premises, the financing may not be seriously affected.

In sustaining this provision in the Miami ordinance the Florida Supreme Court said:

> "The reasonableness or unreasonableness of the provisions of the section complained of must depend largely, and may depend entirely, upon the character of the terrain of the area affected * * *.
>
> "What may be considered an unreasonable requirement to be applied in a village located on the red clay hills of Leon County might be a regulation vitally necessary for the protection of the public health and welfare of the inhabitants of a city, the larger portion of the terrain of which is not more than 10 or 12 feet above sea level and a less distance above the average water table.
>
> "Private rights must always be subordinated to public rights and the public health is as sacred as any public rights can be. * * *"

Ownership of Water System Important

We have another problem in cases where the ownership and operation of the water system and the sewer system are not the same. Fortunately over 90 per cent of the urban population in this country is served by publicly owned water plants. But where a city or a substantial portion thereof is served by a water plant that is owned by a private corporation, can satisfactory arrangements be made with such corporation for computing and collecting the sewer service charges? Will it shut off the water for non-payment of such charges?

Where the pollution is caused by the sewage and wastes from several cities, towns and villages, we have still another problem. In some cities where I have been

working it is expected that the City will construct and operate the sewage disposal system and finance such construction by sewer revenue bonds of the City and then enter into contracts with the adjoining communities for treating their sewage. In some cases where there are several cities and towns, each owning its own sewer system and each being served by a separate water system, it will probably be necessary to enact legislation setting up a sanitary district or a sewer authority covering the entire territory. The preparation of such legislation will not be an easy task and working out the financing plan on an equitable base will be even more difficult if there are any privately owned water plants within the territory.

The Portland Water District as an Example

You may be anxious to have me make some suggestions in connection with your own situations, particularly here in Portland. But, as I have said, the financing plan for each situation must be a tailor-made job. The Portland Water District is a quasi-municipal corporation created by a special act of the Maine Legislature. The District supplies water to the City of Portland and several adjoining cities and towns. I understand that the City of Portland has its own system of sanitary sewers through which sewage flows untreated into the bays and waters surrounding the City, and that the pollution of these waters is now or may soon become a menace to the health of the inhabitants of the City. If this is true, it appears to me that it would be advisable for the City to have a thorough survey made of the situation, in the first instance by its own engineering, finance and legal departments and then, at the proper time, employ outstanding consultants, particularly consulting engineers who have specialized in this particular line, to cooperate in the preparation of a comprehensive plan for construction of sewage disposal works and the financing of such construction. In the preparation of such plan, consideration must be given to many matters, such as:

1—The type of treatment best suited to the situation, the design and location of the sewage treatment works, intercepting sewers, force mains, pumping stations, and other equipment, the cost of construction and the annual expenses of operation and maintenance.

2—The necessity from a health standpoint of constructing sanitary sewers in any unsewered areas.

3—The extent and the condition of the sewer facilities in the adjoining cities and towns and to what extent the sewage from these facilities contributes to the pollution to be abated.

4—If the construction of a sewage disposal system shall appear to be necessary, by what public instrumentality shall it be constructed and operated, and shall such construction be financed by general obligation bonds or revenue bonds? If all or substantially all of the area to be served is within the limits of the City of Portland, perhaps the City is the proper instrumentality. If so, in determining the type of bonds to be issued, consideration should be given to the margin between the present debt of the City and its legal debt limit and the necessity of preserving that margin for other public improvements.

But regardless of the ability or willingness of the City to issue its full faith and credit bonds, I would urge that careful consideration be given to the matter of issuing sewer revenue bonds, payable from sewer service charges to be imposed only upon those who actually use the system. If this plan should be adopted, however, who will collect the bills? The Portland Water District owns the water plant. Would it like to be a collection agency for the City? If so, how will it enforce collection, and will it be willing to shut off its own water for non-payment of the City's sewer service charges?

Perhaps the Water District is the proper instrumentality. It has done an excellent job in bringing pure water to the premises of those who use it. This, however, is only the first half of a complete service. The other half is the disposal of that water after it has been polluted by the user.

Reasonableness of Charges

Financing the construction of sewage disposal systems by the issuance of sewer revenue bonds, payable from sewer service charges added to the water bill, is comparatively new. There have been some objections to this type of financing on the grounds that the improvement is of general benefit to the community and should be paid for by a general ad valorem tax. I have no legal objection to this plan if the financial structure of the city or town will stand it. But it seems to me that real estate is carrying about all the load that it should at the present time. It is taxed for schools, police and fire protection and many other essential functions of government, both state and local, that cannot be financed in any other way. But in the case of many of our public facilities and utilities I believe that it is more equitable to require the users to pay for them.

What Will the Sewer Service Charges Amount To?

In an ordinance which I have recently prepared authorizing Water and Sewer Revenue Bonds to finance improvements of the City's waterworks system and also additional sanitary sewers and new sewage treatment facilities, the initial sewer service charges to pay the principal and interest of that amount of the bonds which are to be issued for the sewer improvements and to maintain and operate the complete sewer system after the construction of the improvements, will be 65 per cent of the water bill, after making proper adjustment for water not entering the sewer system, such as water used in the sprinkling of lawns, for air conditioning, steam production, etc. In another City for which I am working the sewer service charges will probably be as much as 100 per cent of the water bill.

Are such charges reasonable? Let us consider the service which is being rendered by a waterworks system and the service which will be rendered when the second half of the job is done.

The charge of the Portland Water District for delivering 1,500 cubic feet of pure water to the consumer is $2.50. A cubic foot of water weighs 62.3 pounds, 1,500 cubic feet weigh 93,450 pounds, almost 47 tons. In other words, the water user pays less than 6c a ton for water delivered into his home. What do you have to pay up here for a ton of coal or a ton of fuel oil delivered to your home? For the price of a pack of cigarettes you get three tons of pure water. On the basis of the sewer service charges I have just mentioned, you would pay from 4 to 6 cents a ton for taking away and cleaning up the water after you have fouled it.

It appears to me that such sewer service charges should not be considered unreasonable to the people in any community, particularly if they are fully advised through the press and public meetings how serious a menace to their health the present situation is and how small will be their individual contributions to remove this menace.

The people in a community never object to improving their water system in order to effect cheaper fire insurance. Why not provide some health insurance in addition?

For a helpful article on "Modern Methods of Sewage Works Financing," which contains a Model Sewer Rental Ordinance, typical Billing Forms used in collecting Sewer Service Charges, and a tabulation of Sewer Rental Experiences, see pages R-161-165 of the 1947 Reference and Data Number of *Water and Sewage Works* (July 1947) and pages R-177 and R-221 of the April 1946 Number.

SELLING SEWER RENTAL TO INDUSTRY

Experiences and Lessons Learned at Belleville, Illinois

By GEORGE S. RUSSELL*
Cons. Engr., St. Louis, Mo.

THE existing sewage treatment plant in Belleville, Ill., was completed in 1939. The plant is of the separate sludge digestion activated sludge type. It is thought that this plant was originally designed to serve 40,000 people, but due to lack of funds, the aerator capacity was reduced one-fourth. The plant is now overloaded, particularly in the secondary processes, due to the fact that there is a large industrial load which was not planned for in the original design. The average dry weather flow through the plant has been 3.74 mgd. with a maximum of 5.21 mgd. Although the flow is not excessive for the capacity provided, the average B.O.D. of this sewage has been about 400 ppm. Figuring 4.0 mgd. at 400 ppm., the equivalent population would be 78,400 people. As the aerator capacity was reduced to three-fourths of the original design, we can easily see why the plant has become overloaded.

In order to eliminate pollution of the receiving stream and to provide for future growth, it has been decided to increase the capacity of the plant to 6.0 mgd., and a total B.O.D. loading of about 17,000 lbs. It has also been found necessary to make some additions and revisions to the sanitary sewers to take care of the growth of the city and increased industrial loads. These improvements to the sanitary sewers and the additions to the sewage treatment plant will be financed by sewerage revenue bonds. In the development of a rate ordinance to support these sewerage revenue bonds, and in the discussions of this ordinance, we have encountered some interesting reactions which may be of value to others.

Developing an Ordinance and Rate Structure

In the past, for other communities, sewerage rate ordinances have been based on one of three methods.

The first method is to base the service charges, or sewer rentals, on volume alone. This has been accomplished by charging on the basis of the volume of water used where water is metered, or by employing a rate per fixture of different types which could be proportioned on water use.

The second method which has been used, bases the charge on strength alone. One basis for accomplishing this has been what is known as the "equivalent population" method. This method is usually predicated on the number of pounds of B.O.D. discharged to the sewer converted to equivalent population. In this computation the figure usually employed as representing the waste from one person is 0.17 lbs. of B.O.D. per day.

The third method represents a consolidation of the first two, basing the rental charge on a combination of volume and strength of sewage. The City of Akron has recently adopted such an ordinance. It seemed to the officials of Belleville that such a method was the logical one, and the engineers were instructed to develop such a rate structure, comparing the results obtained by this method, with payments to be made under other methods.

The cost of the improvements to be made at Belleville will be approximately $1,200,000. Of this amount, 60 per cent can be charged to provisions to handle volumetric flow, and 40 per cent as being chargeable to strength of the sewage, or B.O.D.

If the B.O.D. of *all* sewage, domestic and industrial, were approximately the same then the volumetric method could be used without any inconsistency. As the average B.O.D. of domestic sewage in Belleville was close to 200 ppm., it was decided to establish rates on the basis of the water used alone, as long as the B.O.D. of the sewage averaged not more than 200 ppm., and to make an additional charge for wastes which have a B.O.D. greater than 200 ppm. Using the figure of average domestic sewage strength at 200 ppm., and per cent of plant cost dependent on B.O.D. as 40 per cent, it is apparent that the *additional* charge for B.O.D. in excess of 200 ppm., should be 40/200 per cent or 1/5 of one per cent. It was also determined that in order to take care of operation and maintenance, and provide net earnings greater than 150 per cent of that required for debt service, the sewer rental charge must be predicated on 60 per cent of the existing water rates. These determinations produced the following proposed rate structure:

Monthly Rates

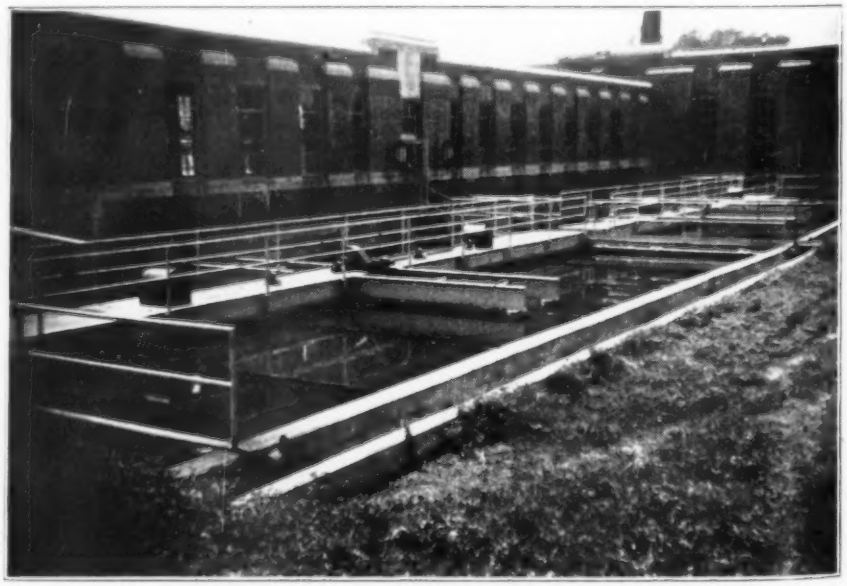
	Cu. Ft.	Rate Per 100 Cu. Ft.
First	13,000	$ 0.20
Next	13,000	0.15
Next	27,000	0.125
Next	27,000	0.096
Next	54,500	0.072
All Over	134,000	0.066

Additional charge—for every part per million of biochemical oxygen demand that the industrial waste exceeds 200, add one-fifth (1/5) of one per cent.

After it was determined that this rate structure would yield the required revenue, the city officials decided to hold a meeting with the larger industries in Belleville for the purpose of explaining the rate ordinance to them and, if possible, secure their endorsement of the program. It was at this point of the program that some difficulties were encountered. Discussions of B.O.D. and equivalent population seemed to leave the industrial representatives cold. They could not find anything wrong with the computations; neither could they get anything tangible out of them. These representatives all stated that they were satisfied if all industries could be put on the same basis, but they were all human enough to feel that their portion of the load was too high.

At this point, in the proceedings, it was decided to hold a joint meeting of the larger industries and to try to impress them with the fact that all computations were based on the same structure. At this meeting a large blackboard was provided and in the upper left hand corner the rate structure previously quoted was set out. Then this structure was used to compute the payments for each of the industries represented at the meeting. Complete data had been secured on the actual flow and the B.O.D. of each of these industrial wastes. The production of the industry during the period of the tests had also been secured. With the average daily flow and the B.O.D. for the particular industry it was easy to compute the average daily cost for each industry represented, and to show that these daily costs were predicated on the same rate structure. This information was, of course, nothing unusual in a study of this kind.

In making these computations, however, one additional step was taken. After the average cost per day was derived, the average production per day was computed. This allowed us to give to each industry the cost of sewer service per unit



Rear View of Belleville's Activated Sludge Plant Showing the Clarifiers.

of their particular product. It was this specific form of information which seemed to be what the industries wanted. The meeting broke up with a general endorsement of the proposed sewerage rate ordinance by the industries represented.

How the Computations Were Conducted

In order to indicate how this work was done, and to give some figures which may be used as a comparison at other plants, we are setting out the computations for five of these industries: two breweries, one packing house, one canning factory, one laundry. We have included two breweries in order to show the effect of volume of production on the unit cost.

For ease of computation we shall first set out the rate structure on a daily basis.

Daily Basis

	Cu. Ft.	Rate Per 100 Cu. Ft.
First	433	$ 0.200
Next	433	0.150
Next	900	0.125
Next	900	0.096
Next	1,800	0.072
All Over	4,467	0.066

Additional charge—For each part per million of biochemical oxygen demand in excess of 200 ppm, add 1/5 of 1%.

Charges for Each Industry

Brewery No. 1

Average daily production 318.6 bbls.; sewage flow 0.1249 mgd. = 16,653 cu. ft./day; average B.O.D. = 724 ppm.

Rate on volume:

433 cu. ft.	@ 20c	per 100 cu. ft.	=	$0.8667
433 cu. ft.	@ 15c	per 100 cu. ft.	=	0.6500
900 cu. ft.	@ 12.5c	per 100 cu. ft.	=	1.1250
900 cu. ft.	@ 9.6c	per 100 cu. ft.	=	0.8640
1800 cu. ft.	@ 7.2c	per 100 cu. ft.	=	1.2960
12187 cu. ft.	@ 6.6c	per 100 cu. ft.	=	8.0434
Total Cost for Volume per day				$12.8451

Extra charge = 1/5 x (724-200) = 104.8%.

Additional charge = $12.84 x 1.048 = $13.46.

Total charge = $12.84 + $13.46 = $26.30 per day.

As this figure is based on producing 318.6 bbls. of beer, the cost per bbl. would be 26.30/318.6 = 8.3c per bbl.

Brewery No. 2

Average daily production 2730 bbls.; sewage flow 1.1 mgd. = 146,700 cu. ft./day; average B.O.D. = 690 ppm.

The total cost of volume, following method outlined for Brewery No. 1, is $98.68 per day.

Extra charge = 1/5 x (690-200) = 98%.

Additional charge = 98.68 x 0.98 = $96.81.

Total charge = $98.68 + $96.81 = $195.49 per day.

The cost per barrel of beer is 195.49/2730 = 7.2c per bbl.

This illustrates the reduction in unit cost with increased production.

Packing House

Total kill during test period of ten days, 130 cattle, 40 calves and 428 hogs, or an average hog equivalent of 98 per day. Sewage flow = .0147 mgd., or 1960 cu. ft.; average B.O.D. = 2451 ppm.

The total cost of volume computed from rate schedule is $2.83 per day.

Extra charge = 1/5 x (2451-200) = 450.2%.

Additional charge = 2.83 x 4.502 = $12.74.

Total charge = $2.83 + $12.74 = $15.57 per day.

The cost per hog equivalent is $15.57/98 = 16c per hog. This price can be materially reduced by better housekeeping and recovery, leading to the reduction in B.O.D. of the waste.

Laundry

Average sewage flow .0225 mgd. or 3,000 cu. ft./day; average B.O.D. of waste = 612 ppm.

The total cost for volume is computed as $3.75 per day.

Extra charge = 1/5 of (612-200) = 82.4%.

Additional charge = 3.75 x 0.824 = $3.09.

Total charge 3.75 + 3.09 = $6.84.

On the basis of 700 gallons of water per 100 lbs. of laundry, the average amount of laundry handled was 22500/7 = 3,200 lbs. of dry laundry. The cost per 100 lbs. of dry laundry would be 6.84/32 = 21c.

Canning Factory

Tests on this industry were confined to the bottling of catsup and the canning of spaghetti.

While bottling catsup, the average daily production was 3309 cases, the sewage flow average 0.0258 mgd., or 3440 cu. ft./day; the average B.O.D. = 1037 ppm.

The total cost for volume is computed as $4.06 per day.

The extra charge = 1/5 x (1037-200) = 167.4%.

The additional charge = 1.674 x 4.06 = $6.80.

The total charge 4.06 + 6.80 = $10.86.

On the basis of 3309 cases of catsup this amounts to ⅓ of a cent per case.

While canning spaghetti, the average daily production was 1445 cases; the sewage flow average 0.1216 mgd., or 16213 cu. ft./day; average B.O.D. = 398 ppm.

The total cost for volume is computed as $12.55 per day.

The extra charge = 1/5 x (398-200) = 39.6%.

The additional charge = .396 x 12.55 = $4.97.

The total charge is 12.55 + 4.97 = $17.52.

On the basis of 1445 cases of spaghetti, this amounts to 1.2 cents per case.

It seems that this reduction of sewage handling costs to a cost per unit of production gives the industry some tangible figure which they can use in revising their cost of production. This analysis is presented with the idea that in many instances in the past our inability to satisfy industry that our methods are sound has probably been due in a sense to our inability to "talk the same language."

Here's Help in Solving Water,

• Link-Belt manufactures a complete line of equipment for Water, Sewage and Industrial Liquids Treatment Plants and have applied this equipment effectively to the solution of such problems. Link-Belt engineers have cooperated with consulting, municipal and sanitary engineers, and plant operators in planning and operating plants, for positive results and highest efficiency. For information on any of the following products, write your nearest Link-Belt office.

SCREENING

1. **STRAIGHTLINE BAR SCREENS** — for removal of solids over ½" in size, from sewage or industrial liquids. Send for Folder No. 1587.
2. **TRASH SCREENS** — for the removal of large floating particles from large volumes of water, thus protecting fine water screens or other water plant or power plant equipment. Send for Book No. 2252.
3. **LIQUID VIBRATING SCREENS** — an efficient and economical screen for the removal of solids from industrial liquids. Units are available in several sizes with coarse or fine screen medium. Send for Book No. 1977-A.

GRIT REMOVAL

4. **STRAIGHTLINE GRIT COLLECTORS** — for the removal of a clean, washed grit with a low putrescible content, the collecting and thorough cleaning operation with Link-Belt grit washer makes further handling unnecessary. Send for Book No. 1942.
5. **TRITOR SCREENS** — are used for the removal of screenings and grit at small sewage treatment plants where grit creates a problem during storm flows. With the Tritor Screen, one mechanism accomplishes removal of both grit and screenings. Send for Book No. 1587.

CHEMICAL MIXING

6. **FLASH MIXERS** — for rapid and thorough mixing of chemicals with water, sewage or industrial liquids. A large, efficient four-blade propellor operates without under water bearing. Send for Folder No. 2042.
7. **HORIZONTAL SLOW MIXERS** — for rectangular tanks where horizontal flow is desired. The degree of mixing can be reduced as the sewage flows through the tank by decreasing the number and changing the pitch of the paddles. Send for Folder No. 2042.
8. **VERTICAL SLOW MIXERS** — for square tanks which can be operated singly or in a series of two, three or four. These mixers will provide efficient mixing and flocculation where vertical flow is desired. Send for Folder No. 2042.

SLUDGE and GREASE COLLECTION

9. **STRAIGHTLINE SLUDGE COLLECTORS** — for rectangular settling tanks, Straightline Collectors with peak-cap bearings, pivoted flights and "Straightline" action provide a combination which can't be beat for efficient collection of sludge and grease. Send for Book No. 1742.
10. **CIRCULINE SLUDGE COLLECTORS** — for round settling tanks. Circuline collectors are equipped with "Straightline" action which assures quick and positive sludge removal from the entire tank floor in one revolution. Send for Book No. 1982.

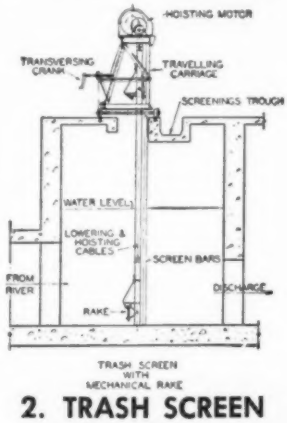
BIO-FILTRATION SYSTEM

11. This system consists of high rate shallow filters and recirculation of the effluent from the filter to the settling tanks. Features are: great flexibility, high rate of B.O.D. loading and the ability of plants to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. Send for Folder No. 1881.

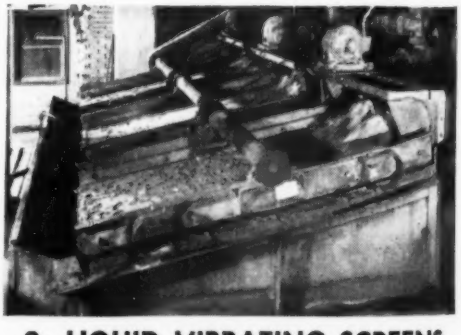
SLUDGE DIGESTION

12. **STRAIGHTLINE SCUM BREAKERS** — are used in either round or rectangular digestion tanks to break up the floating scum, paddle it down and submerge it. The scum breaker consists of two strands of chain with pitched flights between them, traveling at a slow speed. Send for information.

1. STRAIGHTLINE BAR SCREEN



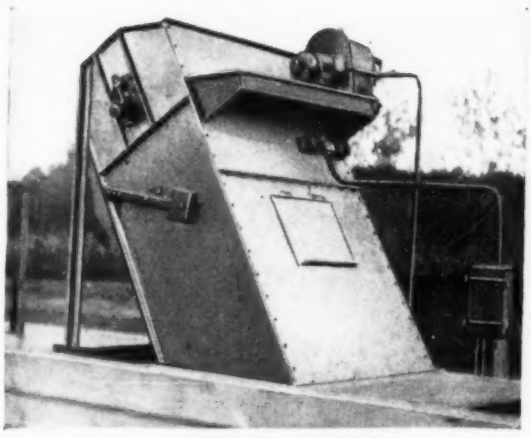
2. TRASH SCREEN



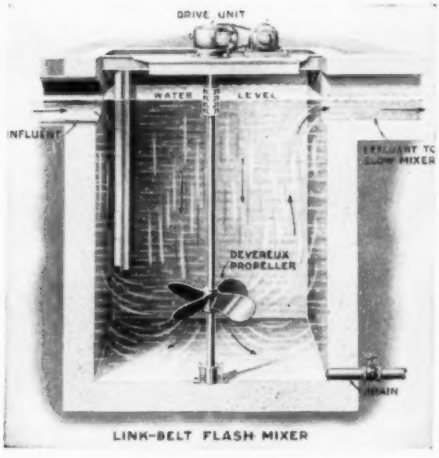
3. LIQUID VIBRATING SCREENS

4. STRAIGHTLINE GRIT COLLECTOR

Sewage and Industrial Liquids Problems

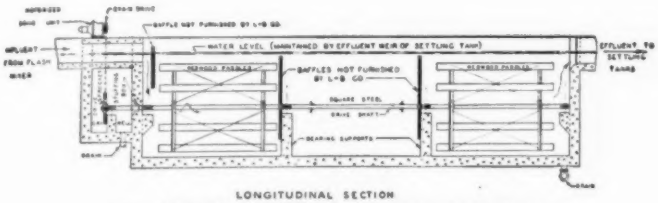


5. TRITOR SCREEN

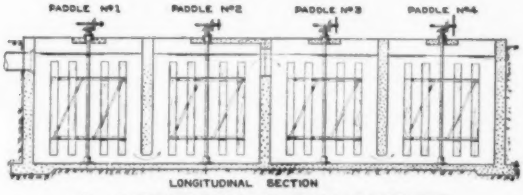


LINK-BELT FLASH MIXER

6. FLASH MIXER



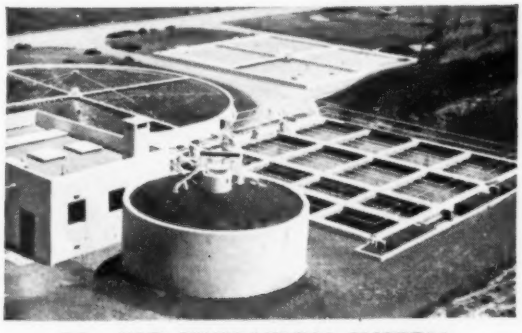
7. HORIZONTAL SLOW MIXER



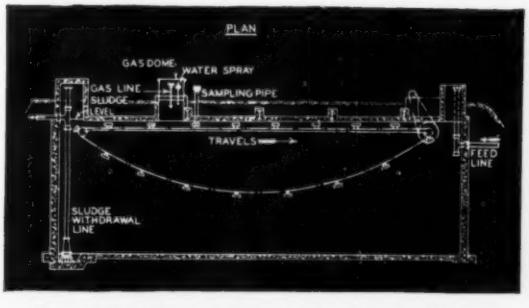
8. VERTICAL SLOW MIXERS

9. STRAIGHTLINE SLUDGE COLLECTORS

10. CIRCULINE SLUDGE COLLECTOR



11. BIO-FILTRATION SYSTEM



12. STRAIGHTLINE SCUM BREAKER

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LINK-BELT

SANITARY ENGINEERING EQUIPMENT

TRENCHING PRACTICE

By RICHARD BENNETT, C.E.
City Engineer, Phoenix, Ariz.

PART I—EARTH TRENCHING

A TRENCH is an excavation having vertical sides and considerable depth in comparison to its width. For purposes of this article it will be considered as being less than 6 ft. in width and not more than 30 ft. in depth, which permits excavation by modern trenching machinery.

Trenches are dug for all kinds of pipe lines, including water, sewer, gas, oil, drains, conduits, etc. The large amounts of trench excavation made necessary by the installation of pipe lines for the various uses has led to many improvements in this practice.

Many of the early forms of trenching machinery such as the traveling derrick, the trestle cable excavator, the tower cableway, the trestle-track excavator, etc., have all given way to the modern ladder type and wheel type trenchers.

Modern trenching machinery was first perfected about 1910. It gives low cost excavation plus fast rate of progress. It is a part of almost every pipe line construction job. Except for very small jobs, hand trenching labor is generally found inefficient and uneconomical. If the ground is free of large, heavy obstructions, and not too hard, the modern trencher is very efficient.

Type of Trencher Most Suitable

The type of trencher to use will depend upon local conditions. If the trench dimensions are small, and much maneuvering is required because of restricted conditions, then some of the smaller trenchers will prove best.

Many consider the wheel type trencher is a harder digger than the ladder type. In hard and tough clays, for medium depths and widths, this type is most efficient. These designs are generally limited in maximum widths and depths of trenches excavated, the maximum being about 3½ ft. width and 8½ ft. depths.

Where trenches of greater width and depths are involved, the ladder type must be used. If stones, not too large, are encountered occasionally, the ladder type is more efficient to loosen them, being partly due to the vibration of the boom, whereas the steadiness of the wheel type excavator would not accomplish the same result.

On most of the ladder type trenchers the boom may be telescoped so that the depth of the trench may be increased or decreased with little difficulty.

In any case, if the digging is difficult, then the high-powered types must be used.

Some trenchers are designed for use in cramped quarters, such as narrow alleys, parkways, close to curbs, buildings or other obstructions, etc. With some the boom may be shifted to one side so that the trench may be cut close to side obstructions.

Maximum service is desired in a trencher. They are subject to hard, grueling service, and their design should sacrifice nothing which would affect durability.

With modern trenchers the spoil bank may be located on either side of the machine, or loaded into trucks or on conveyor as desired. The spoil conveyor will place the spoil bank back from the trench sufficient distance to give a good clean shoulder on which the workmen are not hindered in laying the pipe. When extensions are added to the spoil conveyor the desired height of the spoil bank may be secured to care for the earth from deep trenches.

Parson's "Trenchliner"—250—With Offset Boom
(The boom, now operating at center, may be shifted to any desired position across entire width of chute. Thus the trencher may operate on road shoulders, in narrow alleys, close to curb lines, buildings, trees, etc., without harm or difficulty. The spoil bank can be on either or both sides.)

Trenching Methods

If the trench is deeper than the trencher will excavate, there are two methods which can be used to gain extra depth without undue expense. (a) Excavate with scrapers sufficient depth from the surface and the full width of the trencher so that the trencher can excavate to desired grade line. Several feet of added trench depth can be secured in this manner. The spoil conveyor can be lengthened so that the earth may be removed either to spoil bank or to trucks as desired. (b) Under most conditions it is possible to remove about two feet of earth below the trencher cut, and throw the spoil back onto pipe already laid in place. Using two workmen, one with air spade and the other to shovel, this work can be done at a rather rapid rate of progress. Using the combination of these two methods, several added feet of depth can be economically secured.

Estimating Practices in Trenching

The trenching contractor is beset with many difficulties and uncertainties, therefore estimates must allow for many unpredictable contingencies. It is impossible to know exactly just what will be encountered until the trench has been excavated. The trenching estimator must judge many factors to the best of his ability.

A visual survey of many jobs will enable the estimator to determine, with reasonable accuracy, whether the job will present many interruptions; on the other hand, too much dependence must not be placed on such surveys in built-up areas. Questions concerning wells, excavations, etc., made previously in the area will reveal many facts. Many pipe line contractors have suffered great losses by not familiarizing themselves with the underground conditions to be encountered.

Much experience is required to properly estimate different conditions and proper methods of pipe line work. Some estimators estimate the job as close as existing data will permit, then add a percentage for uncertainties—a method but little better than a shrewd guess. The estimator who can accurately determine costs on two or more methods for the same job, is worthy of his hire.

In pipe line construction, the cost of trenching is usually the major item, depending upon digging conditions. The kind of earth involved makes much difference in the unit costs. These costs increase according to the types of earth, somewhat as follows: light earths and sand; loam and light clays; dry, hard loams and tough clays; dense and tough adobes; coarse gravels, cemented gravels; hard caliche; and disintegrated granites. All these materials produce different unit costs.

Labor Costs

Labor costs are not materially increased with the light earths, sand loams and clays, but such costs are increased with the tough, dense clays, adobes, varying with the amount of pipe bedding required. Mud, especially if it is sticky, will greatly increase costs. Unforeseen conditions, such as solid rock, boulders, water, caving soil and even quicksand conditions will greatly increase costs.

The estimate must include: excavation, sheeting, backfilling, equipment rental; moving to and from job; and if water is likely to be encountered, then an allowance must be included for water pumping and disposal.

The labor expense will include foremen; machine runners, helpers or swampers; pipe layers; laborers; timbermen; backfillers; as well as extra roustabouts. The cost of superintendence and supervision can generally be estimated as a percentage of the payroll.

Fixed Costs

Fuel, supplies, and equipment repairs will generally be a large item with most jobs. To determine the fixed costs per day, the contractor must make assumptions which are later adjusted in the light of actual facts. Some depreciate trencher equipment at 60 months' total life; however, many individual pieces of equipment have lasted both much longer and even shorter time than this. Some authorities estimate yearly costs of this equipment somewhat as follows: depreciation, 20 per cent; repairs, 18 per cent; interest, insurance and taxes, 7 per cent; miscellaneous, 4 per cent. Total fixed charges per year—approximately 50 per cent of original cost of trencher. The total fixed costs per year divided by the units of work performed gives the actual job cost for using that particular machine.

About 4 per cent of the payroll should be charged for small tools. Miscellaneous materials required for the work as the job progresses will generally average about 1 per cent of the payroll. Small jobs, unless the management is excellent, will produce high unit costs.

Daily Cost Analysis Important

The cost analysis of trenching for every job should show the width and depth of trench; type of soil; the total footage excavated; the number of cubic yards excavated; the total overhead and operating expense of the trencher; the daily expense of trenching; the footage expense of trenching; and the cubic yard expense of trenching.

The unit costs should separate excavation; pipe laying; back-filling; cleaning up, moving to and from job; and overhead. The analysis should show minimum, average, and maximum day's work and reasons, together with average of all items for the entire job. These data, kept up daily, will show and determine all leaks and losses on the job.

Cleveland Trencher

(Cutting through a soft-rock formation in Texas called the Austin Chalk. Note the clean cut made. Trenchers of the ladder type are also good in shale, consolidated gravel and all but hard solid rock.)

PART II—ROCK TRENCHING

What was said in Part I on trench excavation in dirt may also be almost wholly applied to trenching in rock. Rock trenching is a time and labor consuming proposition. The fact that it is not often encountered probably accounts for the great variation of methods adopted on different jobs. The technical literature contains almost nothing on this subject. Ask the manufacturer's blasting experts and they merely say, "I will get you something on that." (Period!)

System Lacking in Rock Trenching

Most rock trenching jobs have little or no system. Costs are high, progress is slow, and those in charge make little or no endeavor to find the most economical method for that job.

In rock trenching the quality and quantity of the rock will generally determine the proper method of excavation. For economical work it is necessary to give much thought and attention to the job methods.

The types of rock encountered may vary from hardpan to dense, tough granites; each will require a different method of drilling and shooting.

There does not seem to be any current standard practice in the spacing of drill holes. Each foreman seems to have his own pet ideas—very few of which would stand much investigation from an efficiency viewpoint.

Proper spacing of drill holes will depend on the nature of the rock and local conditions, but cut and try methods must be utilized to ascertain the most economical method.

Drilling Requirements

The number of feet of hole to be drilled per cubic yard of rock to be excavated will vary greatly with different jobs, conditions, and job methods. Spacing will depend upon nature of the rock and width of trench. Properly determining this factor requires much ability on the part of the job manager. This determines ultimate unit costs.

For average rock the following table may be used to determine trial hole spacing:

Width of trench (feet)	Number of rows of holes
3	2
6	3
9	4
12	5
15	6

The outside row of holes should be in line with the trench wall. It is seldom that cross-trench hole spacing greater than 3 ft. can be successfully used. At times the longitudinal spacing can be increased to 4 ft. or even slightly more, especially in the wider and deep trenches. The greatest economy is secured in using maximum depth for holes.

The necessity for protecting adjacent structures, whether underground utilities or nearby buildings, will influence drill hole spacing.

If power excavation equipment is to be used, it is seldom possible to blast a single line of holes down the center of the trench. With but one line of holes too much projecting rock remains to be loosened by prying and barring by hand methods, thus greatly increasing costs.

Care must be taken to keep the drill holes clean until they are loaded. If the hole contains debris or water, this is best removed with compressed air. Ice frozen holes may be cleaned out with steam; this also warms the hole sufficiently so that the explosive will not freeze. A wooden plug should be driven into each hole as soon as the drilling is completed, to keep out extraneous materials; this plug also aids in finding the hole later.

A Well Braced Trench

Proper Quantity of Explosives

Determining the proper amount of explosive to use will require trial and error determination. Experience and good judgment helps very much. In any case carefully kept notes and records are of immense value.

In trench blasting only one narrow face is open, therefore more explosive is required than for open surface blasting. The amount and strength of dynamite to properly use will depend upon all the factors mentioned for spacing of drill holes. The amount of explosive required per cubic yard of rock removed will depend upon the nature and type of rock and the method adopted. The amount of explosive per hole may be limited by the necessity for controlling flying rock, excessive noise or vibrations, and danger to nearby underground utilities or adjacent structures of any nature.

Dynamite is generally used for trench blasting; the grade used depending upon the type and quality of rock encountered. The quantity required may range from about ¾ lb. per cubic yard in soft sandstone to 3 lbs. or more in the hard, dense rocks.

Different rocks and formations do not blast alike to meet given conditions. The specifications for the work may limit the amount and kind of blasting that may be done on the job. Oftentimes blasting is restricted due to local conditions.

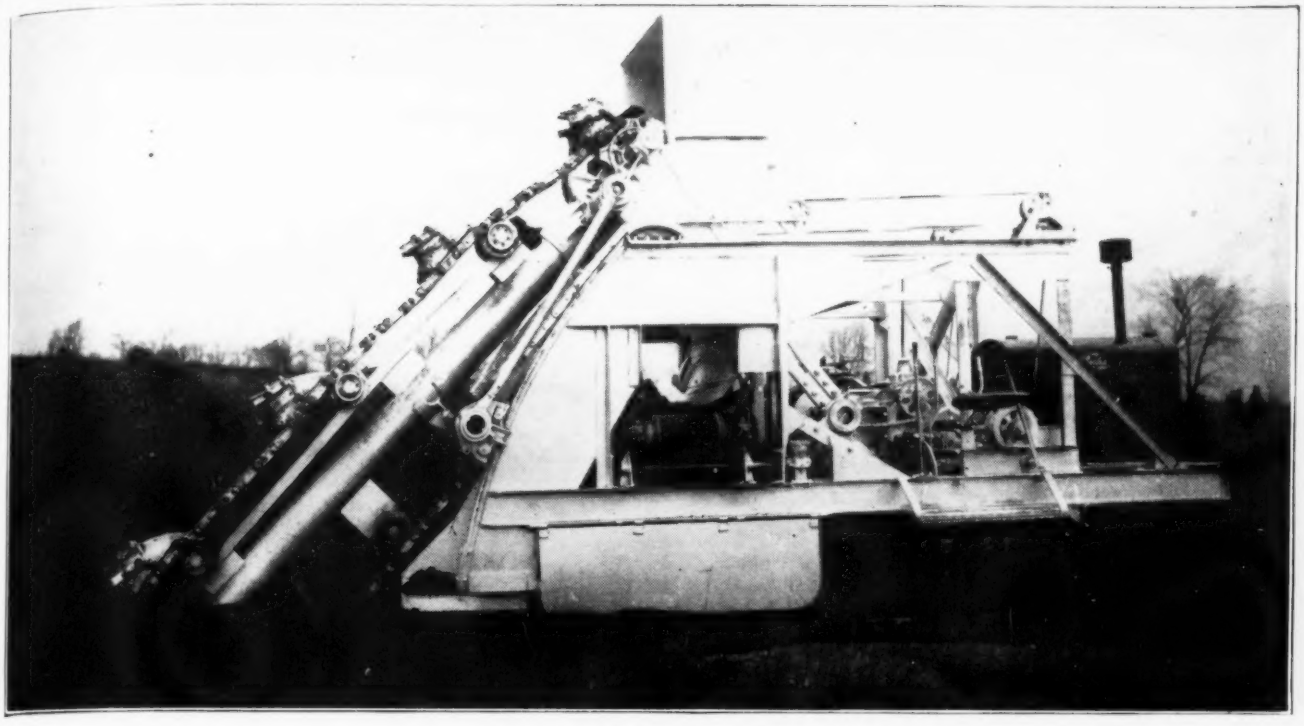
Selection of Proper Explosives

The type of explosive to use will depend upon the type and quality of the rock; local conditions; etc. The greatest waste in explosives is in using a grade or type not suited to the job at hand. A low grade of explosive should be used for soft, weathered rock; to use high grade explosive here, is to waste much of the explosive energy. High power explosives lack propelling power when used in blasting soft rocks.

Too many use only one type and grade of explosive — generally 40 per cent strength. This is poor economy. Some arbitrarily use 60 per cent to secure sufficient shattering and also to loosen rock bound in place. If the rock is not shattered sufficiently, then a higher grade should be used. If the rock is shattered too much, then a lower grade should be adopted for the job.

A high power explosive should be used for hard, firm rock. If the bottom of the hole does not shoot properly, then it may

Koehring's Trench-Hoe
(A rugged piece of equipment, useful where the going is tough—boulders, hard shale, blasted rocks, etc.)



Buckeye Model 120 Trencher

(Buckeye also makes a wheel-type trencher satisfactory for water-line trenching, requiring less depth and permissive of faster travel where the going is easy.)

be best to use a high grade explosive at this point. In such cases place the firing charge at the top of explosives so that the explosive gases will tend to concentrate at the bottom of the hole, thus producing greater rupture at that point.

Sufficient shattering must be secured to permit easy removal of the rock from the trench. It is not possible to use ladder type of trenchers for rock trenching, except in the very soft formations. A pull shovel or trench-hoe may often be used to good advantage in rock trenching.

Rock Excavating Equipment

In shallow trenches the rock may be removed by hand. For hand excavation the rock must be broken into small pieces by either blasting or subsequent breakage.

For deep rock trenches the use of drag line or pull-shovel is most economical. These types of equipment are well suited for this work. The rock must be thoroughly broken up, and the wall sufficiently straight not to hang up the shovel. Rocks too large to be removed by the bucket should be hoisted from the trench with chains.

Limestone is easily drilled. It is occasionally found in horizontal layers, and may be blasted like building stone. In seamy formations, the holes must be closely spaced to retain the force of the explosion. Seamy rocks permit the explosive gases to escape and the full effect is not retained in shattering. Seamy rocks, lying at an angle cause the drills to stick and straight walls may be secured in blasting bind in the hole. Relatively smooth and soft sedimentary rocks.

Granite and igneous rocks break out in rough, irregular walls. If the holes are thoroughly and tightly tamped, then the explosive will give most effective results, due to confining the explosive gases. Trap and quartzite are generally difficult to drill.

Two factors should be kept in mind at all times in rock trench excavation; the number of feet of hole drilled per cubic yard of neat excavation; and the amount and strength of dynamite used per cubic yard of excavation; both of which sum up to: cost of breaking up the rock for satisfactory removal.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

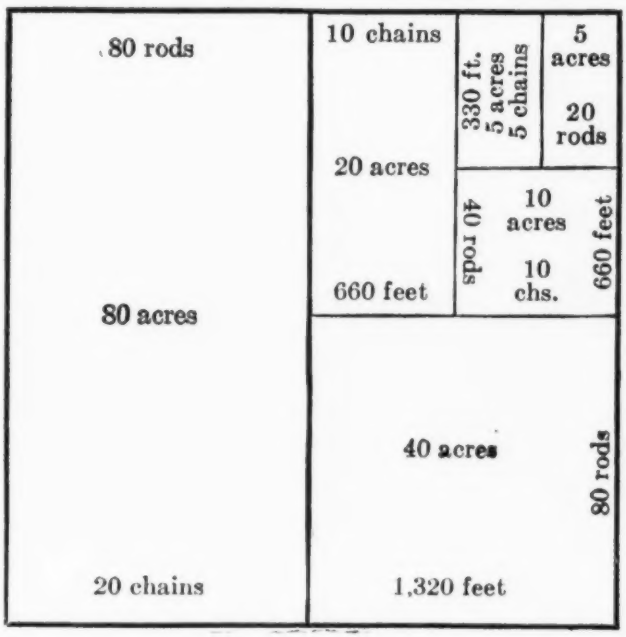
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

An acre is about 208¾ feet square.



GRAPH FOR DETERMINING SIZE OF SANITARY SEWERS

By JOHN G. MONTGOMERY
Civil & Sanitary Engr., Washington, D.C.

INCLUDED with this article is a graphic diagram that will be of some help in determining the proper size of sewer pipes. This graph can be used in determining the increment from all or a single building tributary to the sewer. A check can be made for the proper size of outfall sewers to determine in advance of construction if the city sewer will be large enough to take the "spill."

Such a check will be determined from an example as given in the accompanying table, the data of which are taken from an imaginary plot plan.

Referring to the table it is shown that the total flow for this imaginary plot is 2575 gal. per min. Plumbing engineers, in designing the capacity and size of service pipes, express the amount of water to be carried in "Fixture Units." The "fixture unit" is based on the rate of discharge from various types of fixtures and has been set as equal to a discharge of 7.5 gpm. per fixture unit. Therefore if we divide 2575 by 7.5 it is determined that the flow from that plot of buildings is equivalent to 343 fixture units.

The next step is to refer to the diagram. Enter the diagram at 343 fixture units and proceed upwards on the chart until the line intersects with Curve A. Extend a line from that point on Curve A to the right and to the left. Where this line intersects the "Spill Increment," read 1.22 cu. ft. Continuing to the right this line will intersect one of the pipe size Curves. In this example it is indicated that the pipe size needed will be 8-in. and the slope will be just slightly more than 1 per cent. Thus has been determined the required pipe size and slope. If the sanitary facilities were of the flush tank type, Curve B would be used.

The total expected water consumption in gal. per day can be determined also by extending the horizontal line from the point on Curve A to the left until it terminates at 122 gpm. demand (or 100 times the "Spill Increment"). Obviously this demand does not exist for the full 24 hours, and to obtain the daily flow it is necessary to adjust this demand by the proper capacity (or load) factor which takes into account the number of hours of actual service. This capacity factor is expressed as per cent, being obtained by dividing the service hours by 24. This capacity factor will vary depending on the type of project being served. For example, apartments will have a capacity factor of approximately 50 per cent, hospitals 75 per cent, factories 40 per cent. For the above example, let us assume a capacity factor of 60 per cent. Then the minutes of use during the day will be 864 (24 x 0.6 x 1440). The total daily demand will then be 864 x 122 or 105,410 gal. per day of sewage flow.

It is estimated that the sewage flow is 80 per cent of the water consumption. Therefore the total water consumption in that plot of buildings will be 105,410 x 1.25 or 133,740 gal. per day.

The population to be served by this sewer system can be determined by dividing the total water consumption by 100, thus obtaining 1337 persons.

Table of Data for Sewers in Example

No. of Bldgs. in Plot	Size of Service—Inches	Max. Cap. of Service Pipes—gpm.	Max. Flow Possible gpm.
1	¾	7.5	7.5
2	1½	24	48
2	2	40	80
1	2½	55	55
1	3	85	85
4	4	150	600
5	6	340	1700
Total			2575.5

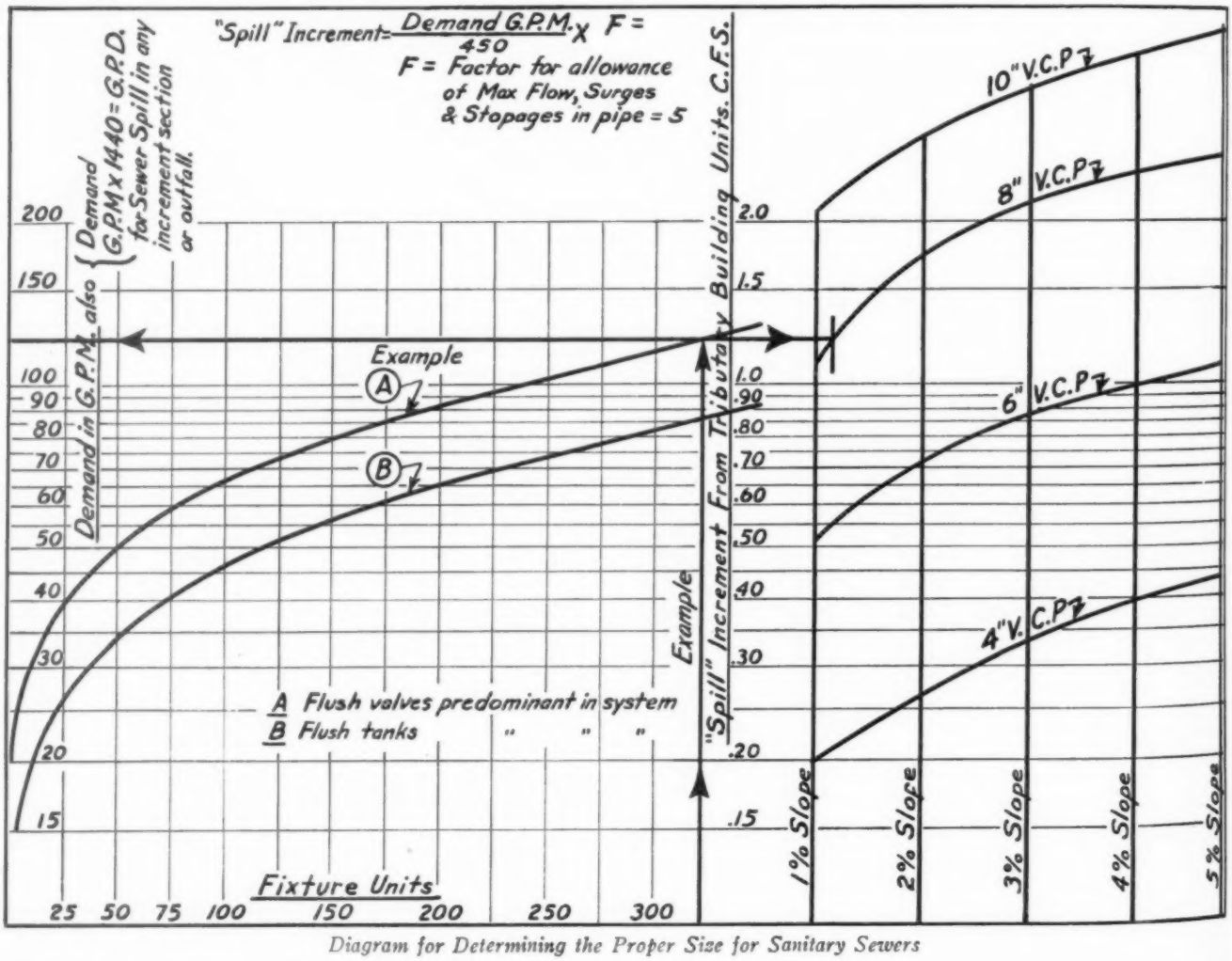

"Spill" Increment = Demand G.P.M. / 450 X F =
F = Factor for allowance of Max Flow, Surges & Stopages in pipe = 5
Demand G.P.M. x 1440 = G.P.D. for Sewer Spill in any increment section or outfall.
Demand in G.P.M. also
Example
A
B
A Flush valves predominant in system
B Flush tanks " " "
Example
"Spill" Increment From Tributary Building Units. C.F.S.
Fixture Units
10" V.C.P.
8" V.C.P.
6" V.C.P.
4" V.C.P.
1% Slope
2% Slope
3% Slope
4% Slope
5% Slope

Diagram for Determining the Proper Size for Sanitary Sewers

LAYING AND JOINTING SEWER PIPES

By FRED C. PALMER
Engineer
Nat'l Sewer Pipe Co., Ltd., Toronto, Ont.

THE question of preventing roots from entering sewer pipes and the annual cost for removing the same, gives considerable concern to sewer departments.

This paper has been drawn from practical experience and experiments, carried out over years, to produce a root-proof and leak-proof joint.

It is also intended to explain, without scientific data and complicated formula, so that the workman, the pipe layer or contractor may be conversant with the many reasons why joints may be defective. The writer is conversant with the many inconveniences and difficulties which confront the contractor and his pipe layer—wet and muddy trenches, threatening storms and cave-in, all of which tend to make difficult the workmanship being carried out.

Roots

Roots will not grow through solid concrete or a solid cement joint, unless there is an opening. They will grow through the very finest hair crack. Roots will not grow through a properly made compound (bitumen joint), but will find their way through a blow-hole or improperly heated compound.

At the tip of a root is a very fine tendril, finer than a human hair. As this tendril grows and reaches a sewer pipe joint, it turns and glides over or under solids, but reaching the finest opening, it enters. Upon entering, the movement of air and flow of sewage draws it in and the warmth of the sewage and its fertilizing properties induce rapid growth. Roots in sewers can be temporarily removed by tools and machines and in some cases their growth can be retarded by the use of chemicals, but they cannot be permanently removed without re-constructing the sewer.

It is not the intention of the writer to deal with the removal of roots from sewers, but rather to suggest means and best methods to prevent their entrance.

Some Types of Joints

The necessity for secure joints is no new problem. Forty years ago engineers introduced the following joints, as shown. These joints are all cast upon the pipes by the pipe manufacturers. (Fig. 1)

Duckett's Patent Stanford Joint (a)

On the spigot and in the socket is cast a bituminous material gradually tapered. Before fitting the pipes together the joints are greased with a mixture of resin and Russian tallow. This makes a tight joint, but it is advisable to finish it off with a seal of cement smoothly trowelled.

Doulton Patent Joint (b)

This is similar to the Stanford with less bitumen and a heavier cement seal. The manufacturer's claims for this joint—imperishable, flexible and can be laid under water.

Tyndale's Patent Double Seal Joint (c)

The convex ring on the spigots makes possible a tighter fit than tapers. The socket of the pipe is deeper and undercut to permit an effective seal with cement.

Button's Patent Joint (d)

These rings are cast with annular grooves. When the pipes are fitted together a grout cement is poured in, which flows and sets between the bitumen rings.

Hassel's Joint (e)

Two cast bitumen rings and two perforations in the socket about three inches apart. After the pipes are fitted together a grout cement is poured into one of the perforations and pouring continues until the grout comes up into the other perforation.

Sykes' Patent Joint (f)

The pipe for this joint is especially manufactured with a flange near the spigot end. The bitumen is moulded in a screw-like thread. Before fitting together a special adhesive cement is spread over the bitumen threads and the pipes are then screwed together. This gives an exceptionally tight joint.

The foregoing joints are shown and described primarily to point out that *expense in jointing becomes secondary to efficiency.*

There are no special joints cast or moulded on sewer pipes by pipe manufacturers in Canada, and the writer is not aware of any joints cast or moulded on sewer pipes in the United States by pipe manufacturers, excepting perhaps special acidware pipe.

There are patent joints, mostly manufactured by chemical companies. These include Patent Rubber Rings, Pre-Cast Compound Joints and Compound for Pouring Joints. These joints require skill and care in their making.

The Rubber or Rubberoid Ring is manfactured to fit the size of pipe required. A cut-back oil is used to aid adhesion, the socket is painted with the cut-back and the ring placed in the socket, then the ring is painted with the cut-back on the inside and on the outside of the spigot and the pipe fitted home. With reasonable care, this is a good joint, but sewer pipes vary in dimensions, such as inside width of socket and outside width of spigot. The variation may be according to the dies of the manufacturer or shrinkage in burning the pipes.

In this, as in any other pre-cast joint, it is necessary to ensure that the pipes used are adaptable to the joint. Some manufacturers supply deeper and wider sockets than others and again some manufacture thicker bodied pipes; and, in burning, sewer pipes vary in shrinkage.

Compound for Either Pre-Cast or Poured Joints

Without going into detail of chemical formulae, Bitumen Jointing Compound consists of approximately 50 per cent asphalt oils and 50 per cent filler, which may be marble dust, slate dust or other aggregate. The heavier the filler, the more difficult it is to hold in suspension; consequently the necessity for repeated stirring during heating and always immediately before dipping out for pouring is evident.

If the compound is left unstirred, the filler sinks to the bottom and on a hot fire will, with the asphalt at the bottom, burn, leaving a residue like coke in the bottom of the pot.

If the compound is poured without having been stirred, the joint will be defective. It will develop blow-holes and through being poured with insufficient filler will overshrink.

When bitumen compound is first used, the pouring temperature as recommended by the manufacturer should be checked with a thermometer so that the workman can become conversant with the appearance and the consistency of the material as it reaches the pouring temperature. Having observed this, he will not need to continuously use the thermometer.

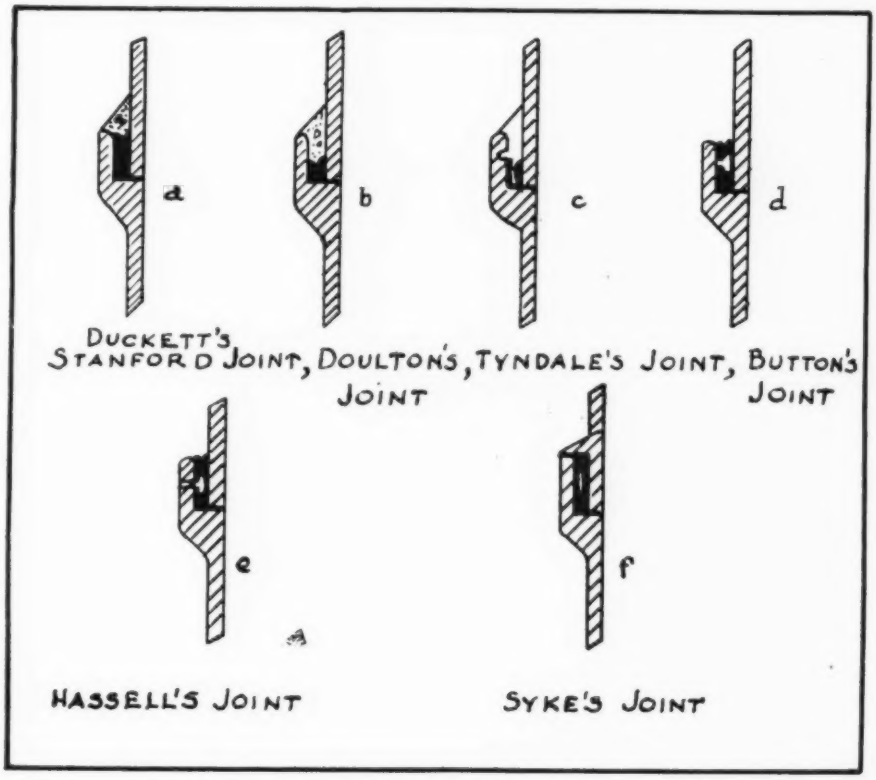


Fig. 1. Special Joints Patented by Engineers

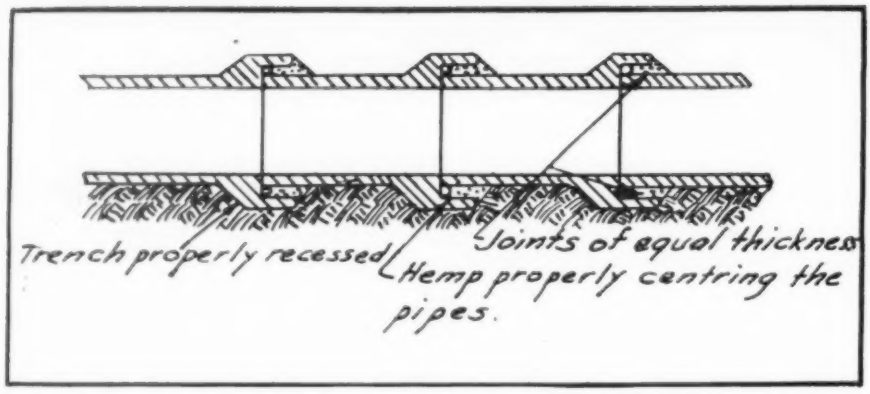


Fig. 2. Correct Sewer Pipe Laying and Jointing

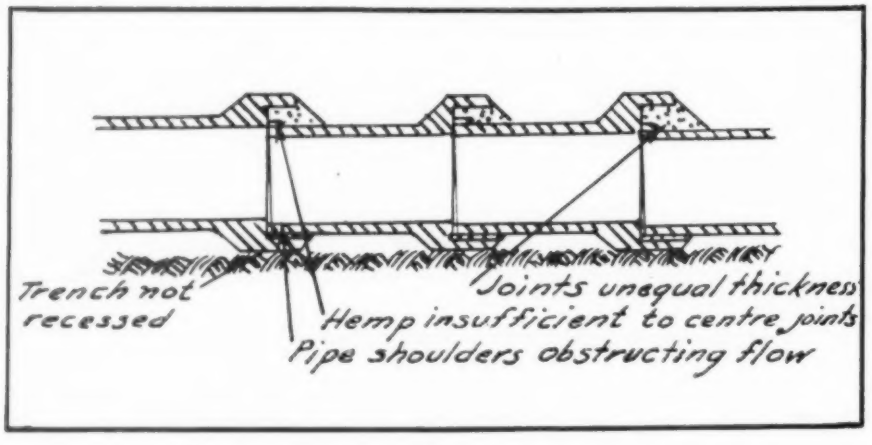


Fig. 3. Defective Sewer Pipe Laying and Jointing

The Trench

Regardless of the fact that the suggested or specified width of trench receives consideration with respect to load on the pipes, a width sufficient to allow proper laying and jointing of the pipe is essential. The use of digging machines and the composition of material to be excavated and weather conditions sometimes prevent the excavating of the trench at a width specified. The trench, naturally, will vary either less or over width.

Four inch to eighteen inch pipe can be straddled by a medium sized man and joints can be made all around from above the socket. Beyond that size, joints have to be made from the sides of the pipe; therefore a satisfactory working width is required. These widths in practice are found to be as follows:

Pipe Size, In.	Trench Width, Ft.	Trench Width, In.	Pipe Size, In.	Trench Width, Ft.	Trench Width, In.
4	1	6	21	3	9
6	1	9	24	4	0
8	2	0	27	4	4
9	2	0	30	4	9
10	2	3	33	5	0
12	2	6	36	5	6
15	2	10	42	6	3
18	3	3			

To ensure good joints the bottom of the trench must be recessed to take the socket of the pipe, as shown in Fig. 2. This is important for two reasons: it gives a bearing along the whole body of the pipe and allows an equal annular space (after the jute or long strand hemp is placed in) to allow a good body of cement or compound all around the jointing space. (Fig. 2)

Laying and Jointing

If the pipe sockets are not recessed, the result will be as shown in Fig. 3. They will be bearing only on socket to socket and the annular space at the bottom of the socket will not be centered sufficiently to hold the required amount of cement or compound. Also, a shoulder causing obstruction as also shown, will be the result.

Juting

Jute, commercially known as Long Strand M.O. (minimum oiled) Hemp is used either with cement or compound in jointing. This hemp is sold in rope form, ranging from 10 to 35 strands loosely twisted. These strands can be separated according to the thickness required to center up the pipe. Hemp is used for two purposes—to center up the pipes as referred to above, and to prevent cement or compound from entering the inside of the pipes.

It is quite improper to see on sewer construction jobs, the pipes standing socket down along a trench, and one or two strands of hemp twisted around the spigot end ready to be lowered into the trench. The pipe layer should measure the circumference of the pipe he is about to lay by putting this hemp around it, then cutting it in lengths 4 to 6 in. longer than the outside circumference of the pipe. He should pull apart from the rope a sufficient number of strands to fill in thickness (not depth) the annular space between spigot and socket. These strands of hemp should be in the trench with him, not put on the pipe before they are let down.

When ready to fit a pipe into another, the hemp is used to guide the pipe into the socket and is carried into the bottom of the socket with it. The top and sides are then rammed in with a piece of hardwood or caulking tool. It is sometimes specified to dip the hemp in a grout cement first. This does improve the joint, when making cement joints.

The pipe layer holds the strands of hemp rope in one hand and puts the rope across his thigh; he rolls it with the palm of his other hand, which twists the strands together, then holding both ends with one hand he can dip his hemp. Then with an end in each hand he places it under the spigot and guides the pipe into the socket.

Compound Pouring

In pouring compound joints considerable time is saved by ensuring that the running rope is secure and tight in or against the socket, as the liquid when poured is liable to run out of the space. It is well to plaster trench clay around the running rope where it fits against the socket.

The running rope is asbestos, square or round. Round is preferable for sewer pipe. Before using, the rope should be well rubbed with moist clay or graphite to prevent the compound sticking to it.

Compound should be poured slowly in a steady stream and continuously if possible. The weather condition (temperature) should be observed. It is likely in cold weather and particularly with 15 inch pipe and over that the compound will set before flowing to the bottom of the pipe. In this condition, it is well to thaw out or warm the spigots with a lighted rag and kerosene.

Cement Joints

When making cement joints in warm or hot weather, the spigot of the pipe or the whole pipe, should be well wetted, otherwise the moisture in the cement at the joint will be absorbed by the pipe and sufficient moisture will not remain in the jointing cement to allow it to set without cracking.

If neat cement for jointing is used, the joint must be kept moist while setting, particularly in shallow dry trenches.

Providing the pipes when laid and jointed are not immediately disturbed by common faults, such as walking on the pipes, climbing in and out of the trench on the pipes, placing a heavy cement pail roughly on pipe where it lodges on the shoulder of the pipe and leans on the side of the trench, immediate backfilling, knocking joints to pieces and disturbing joints newly made or removing shoring too hastily, the writer has obtained best results from the following:

One part portland cement, two and one-half parts clean, sharp sand. Mix dry, then add sufficient water to dampen, then mix (dampen only). Allow to stand forty-five minutes, then add sufficient water to bring to the consistency for good trowelling. This mix and the time allowed to prehydrate with moisture, eliminates shrinkage and gives excellent adhesion.

Recommended Joint

The writer prefers and recommends the following joint, favorable under any conditions, and as near fool-proof as jointing can possibly be. Use a good jointing compound, such as "G-K," or equal. Place a board or plank on the ground near the melting pot (Fig. 4) and measure the width of the annular space between the spigot and the socket of the size of pipes to be jointed. Place two boards upon the

board or plank already placed and space the two top boards the width of the annular space to be filled and have the two top boards thick enough to be two-thirds the depth of the socket of the pipe, or space your top boards at a distance equal to two-thirds the depth of the socket and as thick as the width, either way will do.

Put a good coat of wash (composed of whitening and water creamy in consistency) with a brush between the space of the boards. This is to keep the compound from sticking to the boards. Put a plug of trench clay in the boards at each end or at a distance equal to the circumference of the pipe or pour several lengths at one pour.

Pour the compound steadily backwards and forwards into the opening, leave it ten minutes to properly set. When one side board is taken away a compound strip, rubber like, has been made.

In warm weather this will be found quite flexible; in cold weather the rings can be kept flexible by laying on a board near the heating pot. Fit it into the joint space and caulk the joint with a piece of hardwood or caulking tool, then cement the balance of the annular space. This will give a waterproof and root-proof joint, with a minimum of labor.

In very wet trenches it is suggested that after caulking in the first ring a second ring be caulked in and the cement eliminated.

The importance of laying and jointing sewer pipes has been recognized by the government of the Province of Ontario, which last year passed a bill enabling all towns and cities to license sewer and drain layers. Men doing this work should be classed as skilled labor. They should be made conversant with the engineers' specifications and the importance of proper laying and jointing should be conveyed to them personally by the engineer or inspector.

They should be made to feel that the importance of their work is appreciated and confidence is placed in their ability to do their best under sometimes very difficult circumstances.

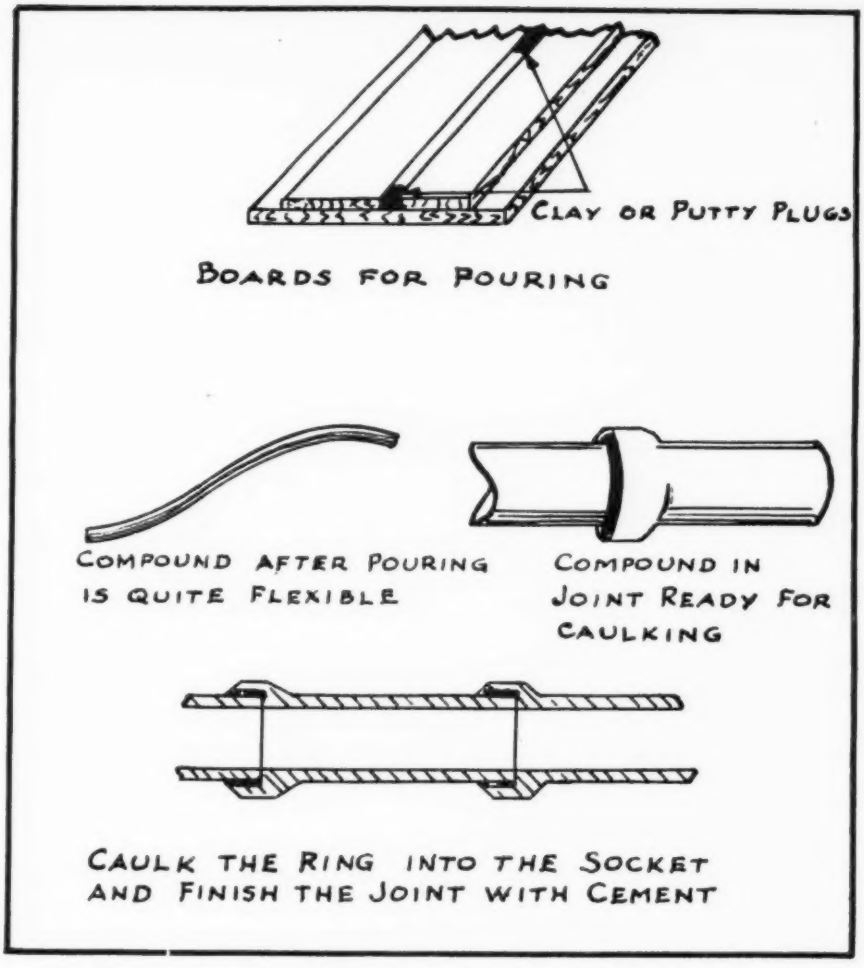

CLAY OR PUTTY PLUGS
BOARDS FOR POURING
COMPOUND AFTER POURING IS QUITE FLEXIBLE
COMPOUND IN JOINT READY FOR CAULKING
CAULK THE RING INTO THE SOCKET AND FINISH THE JOINT WITH CEMENT

Fig. 4. Combination Compound and Cement Joint

Definite and complete specifications by the engineer and co-operation of the contractor and his pipe layer will eliminate root trouble and infiltration.

CARRYING CAPACITY OF SEWER PIPE—GALLONS PER MINUTE

(Based on "Hydraulic Tables" by Williams & Hazen)

Size, Inches	1" Fall in 100 Feet	2" Fall in 100 Feet	3" Fall in 100 Feet	6" Fall in 100 Feet	9" Fall in 100 Feet	12" Fall in 100 Feet	24" Fall in 100 Feet	36" Fall in 100 Feet
4	....	.....	.....	.....	86	102	149	186
6	....	.....	.....	204	256	297	269	534
8	....	.....	.....	437	539	632	921	1143
9	....	.....	.....	601	749	876	1272	1580
10	....	.....	537	781	974	1138	1653	2055
12	....	730	869	1264	1571	1835	2695	3345
15	....	1242	1556	2275	2835	3300	4790	5950
18	....	2030	2510	3670	4580	5340	7760	9665
24	2985	4325	5390	7810	9740	11380	16530	20550
27	4040	5875	7325	10690	13270	15520	22530	27850
30	5340	7760	8670	14080	17500	20450	29750	37150
36	8740	12600	15640	22700	28350	33000	47900	59500

PNEUMATIC GRIT WASHER AND EJECTOR

By NELSON M. FULLER
Superintendent, Water Works and Sewerage
Olean, N. Y.

THE removal of grit at the Olean Sewerage Treatment Plant is a very important detail of plant operation. Large quantities are received from storm drainage and from railroad repair shops. Also large amounts of sewage solids settle out in the grit chamber. Former methods of removal by hand, chain hoist and truck followed by burial were very disagreeable, being akin to cleaning out a large privy each week.

Formerly six man-days were required to carry out this operation, whereas the air lift system now in use washes the grit and disposes of it in thirty minutes. A mechanical conveyor system proposed for the removal of the grit would have cost $5,000. Using scrap materials and our own welders the air-lift pumping equipment herein described cost under $100.

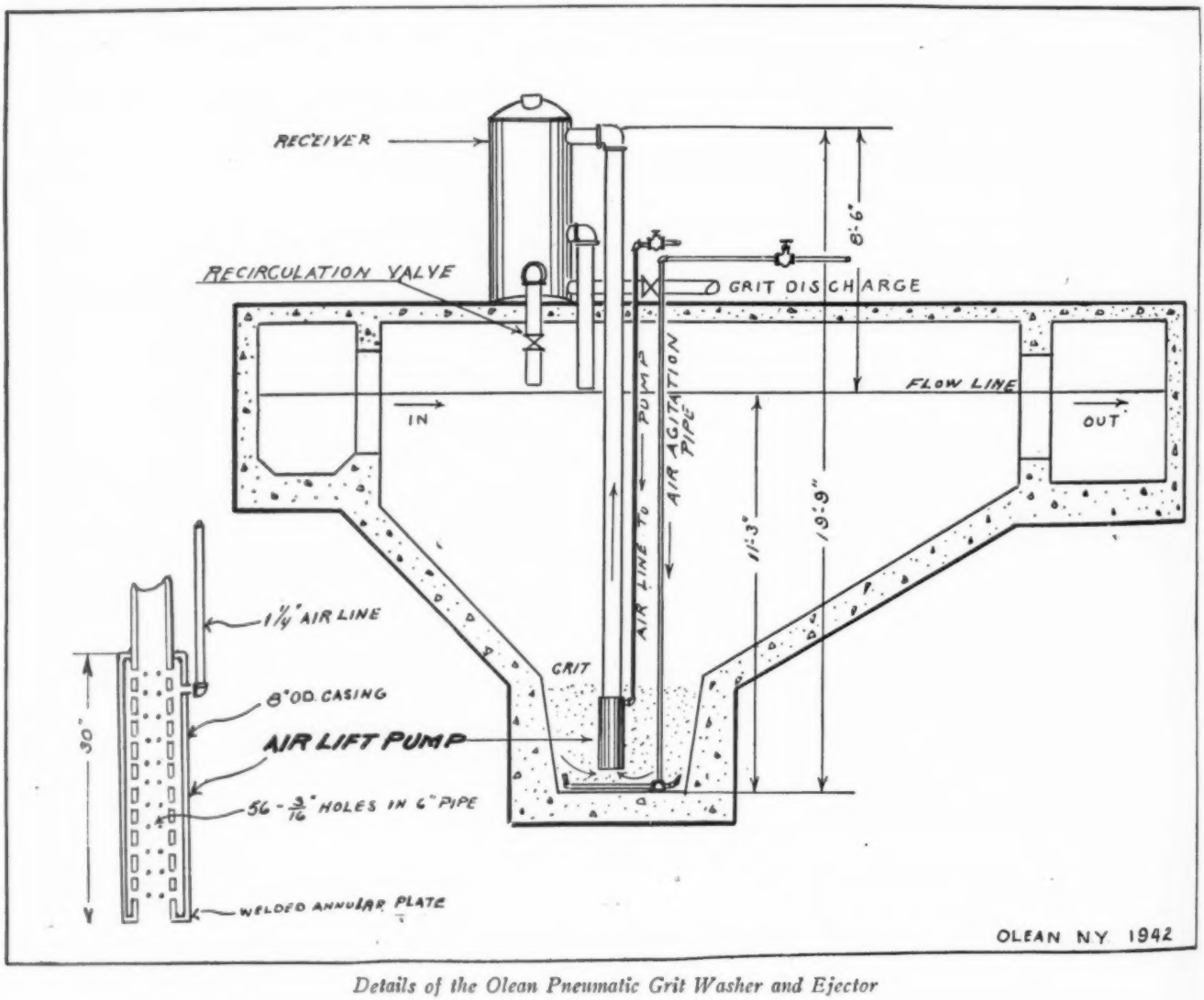
The air-lift system was limited in design to the use of air from our own portable air compressor of 105 cubic foot capacity. This permitted the use of a six inch flow pipe. An air lift pump is simple to construct after the correct size pipe is found which will give a uniform flow without "blowing through." The air water mixture must have a velocity upwards of ten feet per second. The foot-piece (the air and water mixing device) was designed so that in this case no obstruction to the free flow of grit, small sticks, and the rags which sometimes pass the bar screen could get fouled at the entrance.

The sketch accompanying this description shows a detail of the foot piece, which was made by boring fifty-six three-sixteenth holes in a thirty inch section of six inch pipe. This section of pipe was then placed into a piece of eight inch pipe and welded at both ends. The one and one-quarter inch air line was connected into the eight inch casing. A small tank was picked up as junk and was used for the air and water separator or receiver.

It will be observed from the sketch that the grit discharge line from the receiver can be closed and that the grit and solids can be recirculated to secure any desired period of washing action in the grit chamber proper. After a suitable period of washing the grit is allowed to settle and the sewage solids which are then in suspension in the grit chamber are flowed into the settling tanks. When this is completed the washed grit is removed by the air lift pump and discharged to the point of final disposal, which in our case is the Allegany River.

In order to clean out the corners of our grit chamber and to hold sewage solids in suspension air jets have been arranged to agitate the grit in these areas.

There is an excellent paper on this type of air lift adaptation in Sewage Tanks Journal, Volume V, No. 3, pages 509-522, by H. Blunk, Engineer, The Emscher Genossenschaft, Essen, Germany, titled "A Contribution to the Design of Grit Chambers," translated by G. P. Edwards of New York.



Details of the Olean Pneumatic Grit Washer and Ejector

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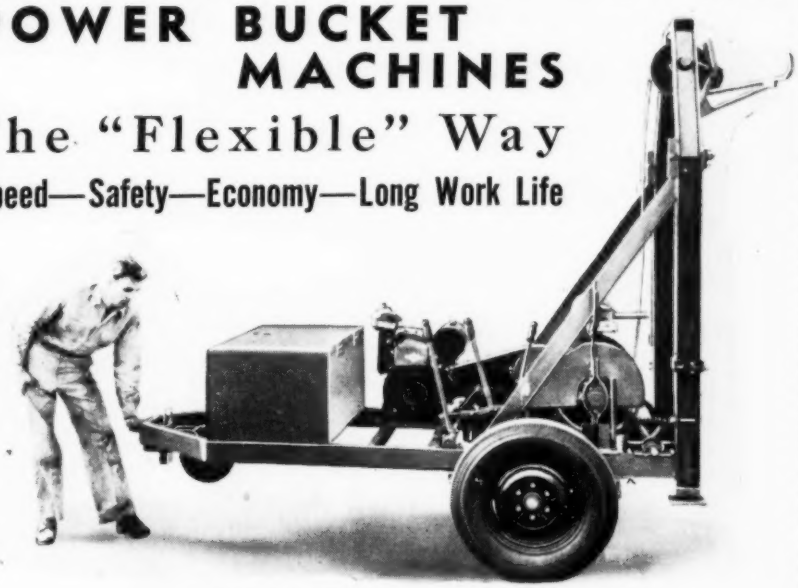

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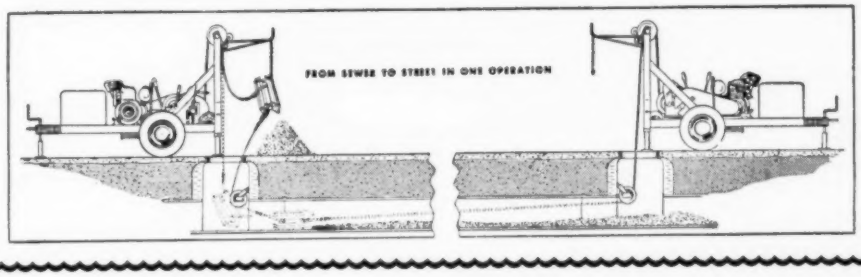

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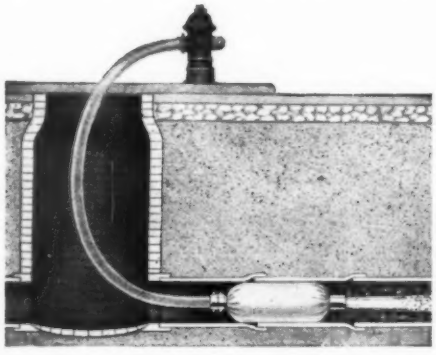
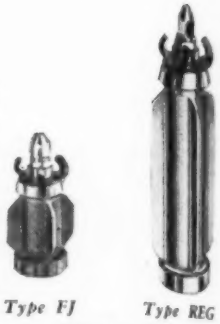


HYDRAULIC SEWER FLUSHING BAGS



Type FJ *Type REG*

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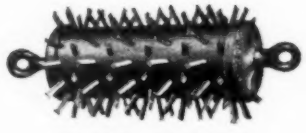

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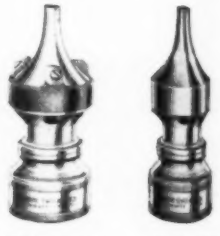

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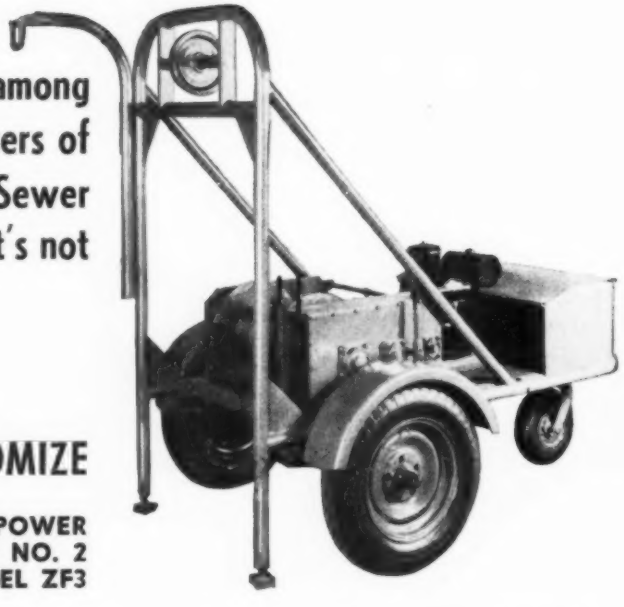

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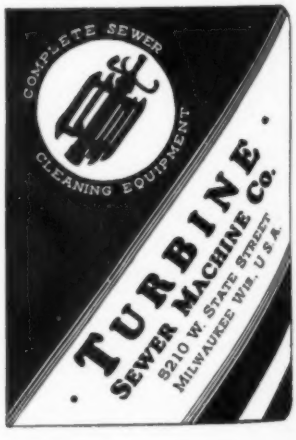

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EXPERIENCE IN SEWER MAINTENANCE*

By W. H. WISELY

Exec. Secy. and Editor, Federation of Sewage Works Assns.

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Sperry, W. A., Supt. Sanitary District, Aurora, Ill.
Steelman, E. S., Mgr., Ocean City (N. J.) Sewer Service.

Of all sewage works operation functions, that of sewer maintenance is usually considered the least pleasant and interesting, yet it is of utmost importance. There is somewhat of an inclination to neglect this essential "chore" in many cases even though the hazards of basement flooding and other effects of faulty sewer operation are appreciated. Good will that has been carefully built up by painstaking public relations activity can be easily destroyed in this way.

Maintenance Program—Records and Inspection

The most important item of equipment in any sewer department is a master map of the system, supplemented by larger scale sectional maps on which are shown important details such as direction of flow, exact manhole locations, sewer sizes and slopes, house connections, etc. Phelps (San Diego) has found that good maps save time and minimize damage to streets and private property, and recommends that all extensions to the system be plotted as made so that the reference maps will always be up-to-date. At Rockville Center, N. Y., Anderson[1] keeps a card index for permanent notes and a log book for daily maintenance notes, both of which are indexed to the sectional maps. The log book is kept by the field crew and records the location of work, conditions found, equipment used and daily costs.

Practice as regards frequency of routine inspection varies widely. Several contributors report that inspections are made only as difficulty arises, while others confine routine inspection to those sewers which have given trouble previously. A number of those reporting this inspection practice indicate that lack of personnel obviates a regular schedule.

Most general inspection practice appears to be as follows: sewers on flat grades or previously troubled by roots—every three months; sewers in which no trouble has been recorded—once to twice yearly; main intercepting sewers—one to four times per month; flush tanks—every month; inverted siphons—one to four times monthly; storm water overflows—during and following heavy rains. Some larger cities maintain a trained inspection crew which is continuously engaged in following a prepared schedule.

Anderson[1] warns that a casual glance into the manhole does not constitute adequate inspection. Steelman (Ocean City) advises inspection of critical sections during peak flows, which advice is substantiated by experience at Urbana-Champaign, Ill., where an 18-inch interceptor appeared to be flowing freely during numerous dry weather observations but was found to be carrying only 25 per cent of capacity when surcharged at the upper end during a very wet season, due to an unusually bad root condition. "Lamping" a section, by looking through the sewer during low flows toward a flashlight (explosion proof) held at the next manhole, is a common method of inspecting lines of 12-inch diameter and larger. Superintendent Case (Merchantville-Pennsauken, N. J.) employs an inspection crew of three men who ascertain the condition of the line by observation at the lower manhole while the line is being flushed or probed with light rods. A change in the color or solids content of the flow will indicate an accumulation. At Birmingham, Mich., the condition of lateral sewers is ascertained whenever an opening is made for a new house service connection.

Where a program of routine cleaning "whether they need it or not" is possible, it is usually correlated with the inspection schedule. At Cimarron, Kan., City Engineer R. R. Crusinberry has developed a schedule of routine cleaning that enables coverage of the entire system every year. At Rockville Centre, where there are 78 miles of sewers, Anderson[1] has planned to clean 26 miles of sewer each year, thus covering the entire system every three years. The work is carried out from March 15 to July 1 and from September to November, totalling about 150 days of the most suitable weather. Work in the business district is done between 4 a.m. and noon to avoid heavy traffic. A similar 3-year schedule for cleaning trunk line sewers, involving work on about 33 miles of sewer per year, has been developed by Superintendent George D. Carpenter at Ithaca, N. Y.

Baltimore, Md., has a well organized plan for continuously servicing the 1,900 miles of sewers and drains in that city.[2] Five crews of three men each are assigned to definite territories and are equipped to clean street inlets and manholes, approximately 1,200 to 1,500 being cleaned weekly. Four crews of five men each are equipped for servicing house connections and small laterals and are constantly engaged in this work. One six-man crew is equipped to work on large sewers and drains. The plan affords continuous maintenance, minimizing complaints and inconvenience to property owners.

Twenty-nine well equipped field crews are able to completely cover the 2,800 miles of sewers in Los Angeles, Cal., twice each year by working according to a systematic plan.[3]

Any routine sewer cleaning program must be arranged to allow for interruptions for emergency calls.

Sewer Maintenance Equipment

The size and type of sewers to be serviced, of course, determine largely the nature of equipment required, but certain items are essential to any efficient crew. Sanitary sewers will usually be troubled mostly by roots and grease, while combined or storm sewers will nearly always accumulate grit and are most likely to receive miscellaneous debris. The equipment carried by the maintenance crew will be most adapted to the character of stoppages anticipated but there must also be equipment for handling the unexpected.

A typical list of essential equipment carried by a full-time, large city maintenance crew working on all types of sewers has been developed from data furnished by the contributors to this article:

Major Equipment

- 2½ ton truck
- Power winch
- Portable, manually-operated winch
- 1,000 feet flexible steel cable
- 1,000 feet fire hose
- 600-800 feet flexible rods (power drive desirable)
- 500 feet interlocking wood sewer rods
- Root cutters of assorted sizes
- Sewer brushes of assorted sizes
- Sand buckets, scoops and drags of assorted sizes
- Turbine flushing heads
- Steel sewer tapes and heavy wire (for small sewers)
- Sewer flushing bags

Minor Equipment

- Shovels, picks and mattocks
- Assorted wrenches
- Hydrant and manhole tools
- Flash lights (explosion proof)
- Rubber boots, coats and gloves
- Buckets and rope

Safety Equipment*

- Hydrogen sulfide detector
- Carbon monoxide detector
- Combustible gas indicator
- Wolf safety lamp
- Hose mask (double) with safety harness

*From "The Operator's Corner," Sew. Wks. Jour. 14, 410, 1942. Reprinted by permission of the Federation of Sewage Works Associations.

*A combination combustible gas indicator, oxygen deficiency lamp, and toxic gas detector is available on the market.

Safety belts (2 or 3)
Complete first aid kit
Manhole guard rails
Traffic signs and flags
Oil lamps and flares

Commenting on the above list, the power winch for pulling scoops, brushes or buckets may be provided for in several ways. There are several excellent portable power units (Fig. 1) available, specifically designed for sewer cleaning, in which the engine, cable reel (with control clutch) and pulley frame are mounted on wheels and can be moved about as a trailer. At Champaign, Ill., the winch is mounted on the truck and is powered by the truck motor.

The sewer service crew of the Joint Meeting Sewer Commission of New Jersey is equipped with several unusual items which have proven highly useful.[8] A short-wave radio receiving set keeps the crew in contact with headquarters regardless of their location about the large area in which they must work; a portable platform derrick expedites heavy loading jobs and is used to transport the sewer cleaning winches; a portable, 1,500-watt generator supplies current for floodlights used in night work and for the portable air blower employed in ventilating sewers and manholes as a safety measure. Portable generators are also carried on some of the sewer maintenance trucks used at Los Angeles.[9]

The sewer maintenance departments of cities of moderate and small size are seldom equipped as completely as listed above, despite the fact that the best of equipment yields greatest economy. Commonly, the general purpose city truck is used to transport loose equipment or pull a small trailer. The truck is sometimes used to pull scoops, drags or brushes as a substitute for more suitable power machines. There is also an unfortunate tendency for small city crews to work without adequate safety equipment and fatal accidents in such crews are much too common. Phelps (San Diego) suggests that the cooperation of the local gas company be obtained when special testing equipment is required for occasional gas surveys.

Character of Sewer Stoppages

The most common obstructions in sewers, in the order of greatest incidence, are (1) roots, (2) accumulations of grease, (3) grit and (4) miscellaneous debris.

Roots generally enter at faulty joints. Growth usually occurs from a single leader root which continues developing inside the sewer until branches from the leader often fill the entire pipe. Phelps reports one root growth 30 feet in length (Fig. 4) removed from a sewer in San Diego. An unusual root removed in San Diego is shown in Fig. 5. Care in making joints, use of proper jointing materials and careful tamping of backfill during sewer construction are good insurance against root troubles later.

Copper, toxic to most plants, has been employed to control root growths. A copper ring, made for the purpose, is available for placing in the joint at the time the sewer is laid. Killing of root growths in sewers by copper sulfate is successfully practiced at San Diego, Cal., and Greenville, Tenn., and elsewhere, a handful of blue vitriol crystals being dropped into a manhole above the suspected root growth, while flow is taking place. Repeated applications may be necessary to kill the leader growth, which later break loose due to the water pressure behind it.

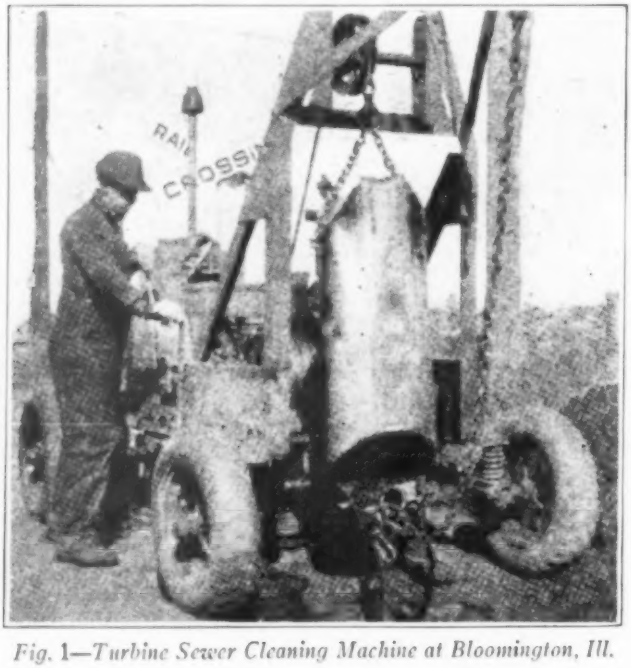

Fig. 1—Turbine Sewer Cleaning Machine at Bloomington, Ill.

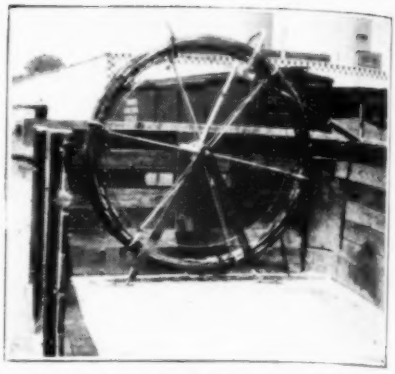

Fig. 2—Method of Using Flexible Sewer Rod Reel in Truck.

Superintendent Case of Merchantville, N. J., reports most root troubles caused by poplar and willow trees and these are removed where difficulty has been caused, to prevent recurrence.

Grease accumulations on the inside of the sewer and in the form of floating balls is a major problem at Atlantic City, N. J.,[4] and other places. Ordinarily discharged to the sewer with hot or warm water, the grease congeals as it cools and adheres to the walls of the sewer or develops into a ball with some small particle or object as a nucleus. These accumulations continue to build up until they materially reduce the capacity of the sewer.

Grit in the form of cinders, ashes, sand, mud, etc., which enters combined and storm sewers with surface water run-off and sanitary sewers with basement drainage, is often troublesome, particularly where sewers are on flat grades. At Rock Falls, Ill., and elsewhere, unpaved streets are the source of excessive grit deposits in sewers. Sewers laid through quicksand often shift due to the unstable foundation, opening at the joints and permitting the fine sand to enter. This condition is serious at East Aurora, N. Y., and, to a lesser extent, at Ocean City, N. J. Mud and sand originating at automobile wash racks is reported to be a cause of grit accumulation in sewers at Kahoka, Mo., and Cimarron, Kan.

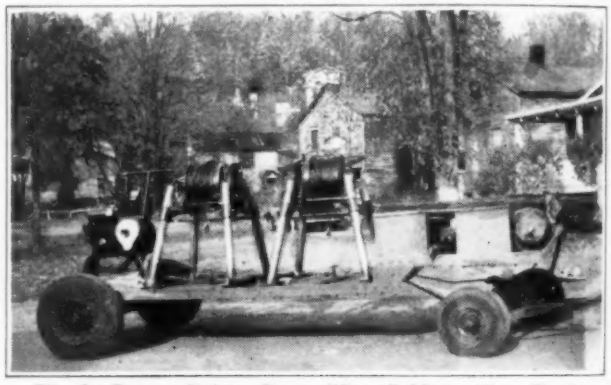

Fig. 3—Power Driven Sewer "Drag" Mounted on Trailer at Ithaca, N. Y.

The character of miscellaneous debris removed from sewers (combined and storm drains in particular) is almost unimaginable. Barrels, posts and a bed spring are on the list at Bloomington-Normal, Ill., and a washing machine was once removed from a large line at Springfield, Ill. Removal of some of these articles demands much ingenuity and patience on the part of sewer maintenance personnel.

Sewer Cleaning

Flushing.—Although not always positive, flushing of sewers is a convenient method of scouring out minor grit deposits and grease accumulations.

Surface water discharges during rains provide adequately for flushing storm and combined sewers, although supplementary flushing by fire hose is employed at Birmingham, Mich., Portland, Ore., and Sacramento, Cal., in conjunction with other cleaning operations, to clean lateral lines and to reduce odors at manholes in extended dry weather seasons. Routine flushing is a general practice in maintaining separate sanitary sewers but the frequencies reported vary from monthly to annually. At Orillia, Ontario, where the sanitary sewers have a minimum

slope of 5 per cent, Engineer L. G. McNeice indicates that annual flushing is practically the only maintenance required. In some cases, as at Ithaca, N. Y., and Kahoka, Mo., routine flushing is limited to critical lines on flat grades, which are flushed every two or three weeks. At Kahoka, some shallow lines are flushed after midnight by means of a time-clock actuated electric valve on the water service, giving a discharge of twenty minutes' duration.

Many old sewer systems were equipped with automatic flush tanks, located at the upper ends of laterals to assure scouring of deposits. Present practice is to design sewers with adequate slopes and the use of such devices is confined to lines in which flat grades are unavoidable. A number of contributors to this article indicate that old flush tanks have been abandoned; others that they are still used occasionally.

From a practical study of the hydraulics of sewer flushing, Watson[8] concludes that the *depth* of the flushing flow in the sewer is equally as important as the velocity. This accounts for the fact that flushing is most effective when the sewer is plugged at the lower manhole, the fire hose used to loosen grit deposits and grease accumulations and, after a head of sewage and water is built up, the plug is suddenly removed to release the flush. Kilpatrick (Rolla, Mo.) emphasizes the importance of blocking the sewer in connection with flushing operations. Sewer "bags," having a hose connection at one end and a nozzle in the other, are available for plugging the sewer and adding flushing water at the same time.

Satisfactory flushing by means of "water wagons" is accomplished at Los Angeles[9] and Lower Merion Township, Pa.[10] In the latter case, water is discharged at the upper manhole from a 625-gallon steel tank mounted on a truck and having a 6-in. drain valve. Discharge is so rapid that an 8-in. sewer is completely filled, giving an effective flush of 500 to 800 feet of sewer.

Hydrogen sulfide formation in sewage is accelerated by the presence of septic sludge deposits in sewers. Bowlus[11] reports that sulfides are definitely reduced after flushing, indicating that the practice is beneficial in reducing odors at manholes and treatment works as well as in reducing damage to sewers and concrete structures.

Removal of Roots.—For cutting and removing root growths in sewers up to 15 in. in diameter, flexible type rods and cutters appear to be very popular, because of the time saved, compactness of the equipment and small labor requirement. An augur-like cutter is used, which is rotated by twisting the rods as they are forced down the sewer. The equipment can be operated easily with two men if the power drive is used, or four men if the rods must be twisted manually. Another advantage of this equipment is that it can be fed into the sewer from ground level and does not require entry into manholes. Accumulations of roots removed at Cimarron, Kan.,[7] are shown in Fig. 6.

For removing roots from larger sewers, or particularly obstinate ones from small sewers, cutting drags are pulled through by cables and winches, either power or manually operated (Fig. 7). This procedure is positively effective, and in many cities is the only method used.

At Ocean City and Merchantville, N. J., every effort is made to prevent recurrence of root growths which are removed from sewers. Steelman at Ocean City reports that defective joints admitting roots are immediately located and repaired and some very troublesome lines have been relaid in iron pipe. Poplar and willow trees causing trouble at Merchantville are removed. Permanent control of roots in house service lines is the aim at Birmingham, Mich., where the city provides 6-in. cast iron pipe with leaded joints to the property line and requires not less than vitrified pipe with asphalt mastic joints inside the property. In case of root stoppage in old cement jointed vitrified pipe services (in the street), the city relays the service to the property line in cast iron pipe for a permit fee of $15.00.

Removal of Sand and Grit Deposits.—When flushing does not produce adequate results, sand buckets or scoops pulled through by the cable and winch outfit are universally depended upon for removing deposits of grit. This equipment (Fig. 1) is positive in effectiveness, regardless of the size of the accumulation.

Where the deposit is not too large, the "Turbine" cleaner which has a water powered, rotating cutter is effective. This device, dragged through the sewer by cable and winch, combines water jet flushing, cutting and dragging into one effective operation.

Rawn[7] describes an ingenious sewer "hoe" used by the Los Angeles County Sanitation Districts for removing grit accumulations from sewers over 30 in. in diameter with a minimum of labor. The device is propelled through the sewer by the pressure of sewage behind it and the invert and sides of the pipe are scoured as it moves. For sewers of 15 to 30 in. in diameter, a beach ball inflated to approximately the size of the sewer is used effectively in the same fashion as the "hoe."

Removal of Grease Accumulations.—Unless of industrial origin, sewer stoppages by grease are confined almost entirely to house services; however the capacity of larger sewers is often reduced due to the development of a grease lining in the pipe.

Flat sewer tapes with various kinds of cleaning tools are used for removing grease obstructions from house connections at Ocean City, N. J. Large sewers give no trouble here. At Atlantic City, N. J.,[8] the most useful device for opening house

Fig. 4—A Few Roots from a San Diego Sewer.

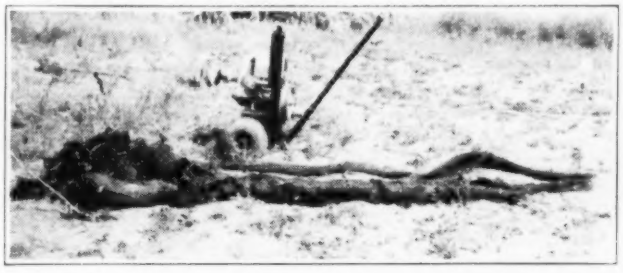

Fig. 5—Not a Sea Monster—A Root Removed in San Diego by Power Driven Flexible-rod and Cutter.

Fig. 6—Root Removed by Flexible Sewer Rod Equipment at Cimarron, Kas.—City Engr. Cruisinberry at Right.

connections has been found to be a 50-ft. length of quarter-inch steel wire. The end started into the sewer has a 6-in. bend which is rotated by cranking the other end as the wire is fed, thus gouging out the stoppage.

Grease accumulations in larger sewers are loosened to some extent by flushing, root-cutting and other maintenance operations. Sewer brushes, dragged through by the ever useful winch and cable equipment, are most positive, however, and many well-trained crews always use a brush drag to finish up a line that has been dragged with other tools.

Other Cleaning Devices.—It will be noted that certain types of equipment are best suited to specific cleaning problems, yet it may often be necessary to use practically all of the equipment carried for cleaning a single line. For instance, the flexible rod and root cutter and/or detachable wooden rods may be used to partially open a stoppage to permit a cable to be threaded through for use in dragging, and several types of drags may be employed. Unusual situations will often demand considerable thought and ingenuity on the part of the maintenance crew even though they are well equipped for ordinary problems.

The sewer "hoe" and beach ball cleaners described above are examples of such ingenuity. The Los Angeles County Sanitation Districts, where these labor-saving implements were devised, makes root cutting drags for 12 to 36-in. sewers from steel pipe[7]; sewer brushes at Ithaca, N. Y., are made from old street-sweeper brooms; a knot of old chain has been found to constitute a serviceable root cutter and drag at Portland, Ore.; a 15-in. root cutter was made to service an 18-in. sewer at Urbana-Champaign, Ill., by wrapping the periphery with barbed wire, further illustrating actual practice in meeting local problems.

Ground Water Infiltration

Although most ground water infiltration results from faulty sewer construction (poor joints or failure to use proper pipe through critical water-bearing soil formations), good maintenance and operation practices can reduce this problem. In referring to infiltration, nearly all of the contributors to this article mentioned the relatively new asphalt mastic jointing compounds as a curative measure, either in explaining why there was no serious infiltration problem or describing how it is being minimized in new extensions or old sewer repairs.

Where there is ample sewer capacity, gravity flow and no sewage treatment works, there is an inclination to disregard infiltration to some extent. Usually the allowance for infiltration in the design of separate sanitary sewers is only nominal but such leakage often proves to be of serious consequence, as at Ithaca, N. Y., where it amounts to 100 to 400 per cent of the dry weather sewage flow due to broken pipe and poor joints. Superintendent Carpenter indicates that correction can be accomplished only by replacement of the defective lines by cast iron or other suitable pipe.

Where sewage must be pumped, it has been found economical to locate and actually replace those lines admitting large amounts of ground water. This has been done at McHenry and Fox River Grove, Ill., Rolla, Mo., and elsewhere.

Steelman (Ocean City, N. J.) and Bridges (Kahoka, Mo.) point out the necessity of careful control and inspection of house connections to minimize infiltration. The sharp increase in flow in sanitary sewers during rains is usually caused by illicit downspout connections which are most difficult to control since many of them are changed after the installation inspection is made. Constant vigilance, public education and rigid enforcement of ordinance provisions are the only possible means of minimizing this source of extraneous water. Kahoka, Mo., and Birmingham, Mich., sewer users are required to comply with strict specifications for workmanship and materials in constructing house sewers.

Maintenance of Appurtenant Sewerage Structures

Aside from ordinary inspection and replacement of broken manhole covers, it is important that manholes in unimproved or semi-permanent streets be maintained at the proper elevation. Considerable damage to such streets is done when an attempt is made to find a manhole which has been covered. Rattling manhole lids often create a nuisance and correction has been accomplished by: application of tar or asphalt around the entire rim or at three or four points[10]; gaskets of rubber, jute or canvas; machining of the lid and casting; use of mechanical locking lids or low center of gravity types. Anderson,[1] after trying several methods, now uses a tape packing made for the purpose which is placed around the entire periphery after thorough cleaning of the casting.

Other appurtenances common to separate sanitary sewers are inverted siphons, creek crossings and flush tanks. Inverted siphons must be inspected frequently as they are readily clogged by accumulations at the inlet or grit deposits in the siphon pipes. Two siphons on intercepting sewers at Champaign-Urbana, Ill., are inspected at least weekly and cleared of inlet accumulations. Three siphons at Ithaca, N. Y., are flushed out every four months. Creek crossing structures are generally checked following wet seasons to ascertain erosion damage, replace protecting rip-rap or make repairs. Flush tanks maintained in regular service are inspected monthly and afforded cleaning and adjustment.

Frequent cleaning of catch basins on storm or combined sewer systems is justified by the protection they provide against grit deposits in the sewers. Practice appears to be to clean these at least annually where paved streets are drained and more often when streets do not have a permanent surface. Street inlets are inspected and cleared after every rain at Rock Falls, Ill., to assure good street drainage. Storm water overflows are inspected and given necessary attention at least once monthly at Birmingham, Mich., and Bloomington, Ill., with more frequent attention being accorded in wet seasons. Sewage flow regulators and adjustable overflows in combined systems are best attended during high flows so that they may be adjusted to actual operating conditions.

Regulation of Use of Sewers

Probably no other public utility is misused to so great a degree as is the sewer system, yet there is always readiness on the part of the public to criticize faulty operation. This condition is no doubt largely due to the lack of public education and to the failure of city officials to adopt and *enforce* proper ordinances controlling the usage of sewers. Such an ordinance does no good if merely filed among the dusty archives of the municipality—it must set forth proper practices, contain adequate penalties and be enforced without hesitancy when courteous requests for cooperation are ignored.

Anderson[1] points out that the best way to obtain public cooperation is to definitely allocate responsibility for house sewer connections to the property owner, requiring him to pay for any maintenance work necessary on these lines. Many eastern cities have established a policy of accepting responsibility for all sewers outside the curb, which practice appears to have several advantages. The Atlantic City Sewerage Co.[8] requires a trap on each house service at the curb and responsibility in each case is determined by examination of the trap. The company services all sewers outside the curb and local plumbers perform at the property owner's expense any work needed from the curb to the house.

Among the more important items warranting inclusion in the sewer ordinance are:

1. Control over location of certain trees (poplar and willow) which might cause root stoppages, including authority to remove such trees found to cause trouble.
2. Prohibition of downspout and similar surface water connections from separate sanitary sewers.
3. Provision for detailed inspection by competent personnel of all house service installations. Also rigid specifications covering workmanship and material in house services.
4. Requirement of suitable preliminary treatment facilities in commercial and industrial concerns to prevent damage to sewers. Wastes commonly controlled for this purpose are: (a) Greasy wastes from restaurants, packing plants, etc.; (b) oil and dirt from automobile filling stations and wash racks; (c) Inflammable and explosive wastes from cleaning establishments; (d) wastes containing excessive solids, such as spent grain from breweries, paunch manure from packing plants, ashes, garbage, etc.; (e) corrosive wastes, as those from metal galvanizing and pickling plants.
5. Requirement of suitable preliminary treatment facilities in industries to prevent interference with sewage treatment plant operation.
6. Provision for stern penalties for malicious damage by vandals.

A combination grit and oil trap recommended by the South Dakota Board of Health[9] for use on sewers from garages, filling stations and automobile wash racks is shown in Fig. 7. The oil problem is successfully met at Baltimore[2] by requiring by ordinance that such waste be stored on the premises until collected periodically for disposal under direct control of municipal authorities. The provision of a convenient means of disposal of the oil eliminates need for policing garages and similar establishments.

After a bad fire caused by waste oil and gasoline dumped to sewers at Aurora, Ill., Superintendent W. A. Sperry acted to prevent a recurrence by means of newspaper publicity and direct contact with industrial sources of volatile wastes. The latter was accomplished by a plant-to-plant canvass of 245 industrial and commercial establishments, during which a verbal notice

was given a responsible representative of each concern, a poster epitomizing the sewer ordinance was left and a signed acknowledgement of each visit was obtained. The survey cost $100 and appears to be good insurance against future damage, although it must probably be repeated after several years.

Sewer Ventilation

Ventilation in sewers is necessary to dilute and purge the system of gases which are inflammable, explosive, asphyxiant and toxic. In warm climates where hydrogen sulfide is often a problem, ventilation is also beneficial in controlling disintegration of concrete sewers and structures because (a) the concentration of H_2S in the atmosphere and (b) collection of moisture on exposed surfaces, are reduced.

The degree of effective ventilation in a sewer is usually dependent upon the amount of vent openings and the movement of air across the openings. Thus, it appears that natural ventilation is at a minimum on still days.

Forced ventilation has been found justified in large outfall sewers at Los Angeles[9] and several ventilation stations are in development. Ordinary ventilation practice is probably represented by the procedure at Lower Merion Twp., Pa.[10] "Ventilating covers" having eight 1-in. openings are placed at the upper ends of all lines and approximately at each third manhole, with consideration being given to surface water drainage and proximity to points at which odor might be troublesome, when selecting locations. Buckets are hung beneath ventilating covers to catch debris which might pass through the openings.

To guard against fires and explosions and to eliminate conditions dangerous to sewer maintenance personnel, the city of Los Angeles[9] has a gas survey crew which systematically checks the entire system, making observations at about 60,000 manholes per year. Results of various gas detector tests are recorded and used as basis for correction of dangerous conditions. When the presence of illuminating gas is suspected, the utility company is immediately notified so that any gas main leak may be repaired.

Design and Construction Items Facilitating Maintenance

Good design and careful construction of a sewer system will reduce maintenance to a minimum and expedite such work as is necessary. There has been sufficient experience at this time to substantiate present methods of ascertaining sewer sizes and grades, yet there is often a tendency to violate the limitations of good practice, particularly with respect to grades. Every effort to avoid capital and operating costs of pumping stations is certainly justified, but consideration must also be given the less satisfactory service and everlasting maintenance expense which accompany the installation of sewers on flat grades. Where moderate reductions in slope are logical, provision of adequate, suitable flushing facilities constitutes good practice.

The prevalence of difficulties from roots and ground water infiltration is ample proof that too much care cannot be taken in specifying and installing permanently tight joints. This fact, of course, is generally appreciated and modern jointing methods and materials are already demonstrating their superiority. Careful specification and performance of back-filling is also important in preventing crushing of pipe and movement which results in opening of joints. The use of especially suited pipe and construction methods in sections where foundation conditions are bad or where excessive ground water is present, has been proven to be good economy, even though more expensive in first cost.

Other design and construction details suggested by maintenance personnel as being of importance to their functions are the following:

1. Design of junction chambers so that back-water areas of low velocity, causing deposition of grit, are avoided.
2. Design of storm water overflows so that they are not accessible by vandals.
3. Catch basins of ample size at storm water inlets draining unpaved streets.
4. Complete consideration of local conditions when selecting the type of pipe used for sanitary and industrial sewers.
5. Spacing of manholes not more than 350 feet apart.
6. Lateral sanitary sewers of not less than 8 inches diameter.
7. Smooth flow without splashing or turbulence at manholes or appurtenant structures. (Important where hydrogen sulfide might be a problem.)
8. Diversion and regulator devices of simple design and capable of convenient adjustment.

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Fig. 7—Manually Operated Sewer "Drag" in Ithaca, N. Y.

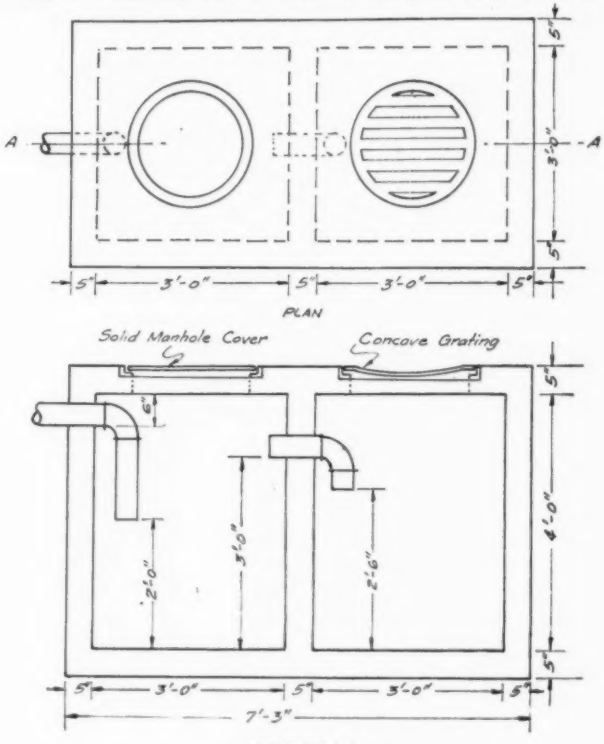


Fig. 8—Combination Oil Trap and Grit Basin for Garages and Filling Stations. Recommended by South Dakota State Board of Health.

COPPER SULFATE AIDS SEWER MAINTENANCE AND SEWAGE TREATMENT

By JOHN W. HOOD
Superintendent, Sewage Treatment, Ridgewood, N. J.

SINCE the original article on this subject appeared in the March 1942 issue of *Water & Sewage Works*, many requests for supplemental information have been received by the author from city, town and state officials in the United States, Canada and South America. These correspondents included state departments of health and city engineers; foresters; city managers, mayors and commissioners; arborists; restaurateurs; superintendents of public works, sewerage systems and sewage treatment plants; and private citizens. These letters denote the widespread interest in the subject matter, and reveal the extent to which this problem of root infiltration had made itself known.

It is superfluous to state that the interest was not in the roots themselves, but in the sanitary, economic, and aesthetic problems created by their infiltration. Private citizens and public officials are frequently found apathetic to proposed root control programs, the exceptions being invariably those who have already had experience with flooded cellars and interrupted sewer service.

Reasons for Root Removal

In addition to the home owner's problem, which stems from the obstruction of sanitary sewer service pipes, there are others which although not so generally appreciated, are of equal or greater concern. These include deterioration of sewers and appurtenances such as manholes and underground structures, sewage treatment plant units and mechanisms, odor nuisances, sewage purification difficulties, inadequate treatment and enhanced costs.

It should be understood, however, that tree roots are not exclusively responsible for production of malodors. Sludge deposits and slimes in sewers are also responsible for objectionable odors.

The benefits to be derived from the use of copper sulfate in sewers and house connection pipes based upon a decade of experience at Ridgewood are as follows:

1. Odor control in the collection system and plant.
2. Reduction in chlorine requirements.
3. Improved and more economical treatment at plant.
4. Root removal and elimination of unsanitary stoppages.
5. Clean sewers free from obstructions that reduce carrying capacity.
6. Clean force mains, enabling pumps to maintain capacity and efficiency.

Explanatory

In order to understand how tree roots in sewers can cause the impairment of structures and destroy the efficiency of purification processes, it is first necessary to consider the character of the sewage passing through the pipes. Sewage has been defined as a heterogeneous collection of inert and decomposable waste matter, soluble and insoluble, dispersed in large volumes of water. Unlike clean water, sewage is a dynamic semi-liquid, constantly undergoing change.

Collection systems are designed to promptly convey this semi-liquid in a "fresh" condition from homes and other points of origin, to the treatment plant. Here the liquid and solids are segregated and treated in separate structures by different processes, the liquid undergoing oxidation (aerobic decomposition) and the solids, digestion or reduction (anaerobic decomposition).

The purified liquid flows to a receiving stream and the dewatered residue from the digested solids may be used as fertilizer or

NOTICE

Village of Ridgewood

Department of Sewers

Obstruction of sanitary house connection pipes by root growths is responsible for the interruption of sewer service and the attendant unsanitary conditions.

Considerable expense is also incurred by the Property Owner and the Village at large, in removing these obstructions.

Owing to the increasing number of these undesirable stoppages occurring throughout the Village, preventive measures have been devloped to destroy these growths.

An employe of this Department will call on you in the near future. His work requires only a few minutes and your cooperation is respectfully requested.

Albert J. Faber,
Commissioner of Public Works.

fill. When a root mass obstructs a sewer pipe, the solids are retained on the upstream side, while the filtrate seeps through the mass. This condition affords an ample structure within which the evolution of anaerobic life and activity is established, favorable factors being little or no atmospheric oxygen such as would normally be present in an unobstructed and therefore well ventilated sewer; a warm liquid media and a constant supply of food in the form of decomposable organic matter.

Micro-biological processes such as occur in soil, convert the waste matter to simple dissolved state, thus making it available as food for the tree roots to draw on. This condition may prevail for a long time before a complete stoppage reveals its existence. Meanwhile, the "fresh" semi-liquid from the homes is being transformed into a highly decomposed and offensive condition even before it leaves the house connection pipe. Not only is the scouring action destroyed but the septic condition created in the sewage are conducive to further biochemical change, productive of further "reduction" (loss of oxygen) attended by malodors and extensive filamentous fungi growths.

The presence or absence of oxygen in water dictates in a large measure, its freshness or staleness. In the case of sewage, it is extremely important to maintain "fresh" conditions, not only for odor prevention, but also to ensure the integrity of structures and subsequent effective and economical purification, either by biological oxidation or chemical treatment processes. The process of reduction is diametrically opposed to the oxidation process employed at the plant to purify the liquid sewage and may preclude satisfactory treatment results.

Sulfuretted hydrogen odors, sewerage systems and sewage treatment plants have been closely associated in the public mind for so long, that they are accepted as a somewhat inevitable combination.

Fuller[1] states "There is no known way of preventing the formation of H_2S which is released from organic sewage matters by a great variety and perhaps most kinds of bacteria . . . in the event that it is true that there are but very few species of bacteria capable of producing H_2S through the reduction of the mineral sulfates, it may be feasible to find some way to destroy such growths. It would be better yet to find some means of preventing such growths from becoming seeded in works, on account of the importance of guarding against the resulting solvent actions that disintegrate masonry and metal structures . . . . ."

Root Removal

The general practice is to employ some mechanical means to cut and remove the offending roots after their presence has been disclosed by sewer stoppage. Due to the size of root stems and damage to vitrified pipe hubs or bells, caused by lateral expansion during growth, it is frequently found necessary to dig up and re-lay the connection. This is a costly and messy procedure and cases on record show that this is no guarantee of freedom from further trouble. As a last resort, many valuable trees have been cut down in order to maintain sewer service uninterrupted.

One eastern city forester reported having "60,000 shade trees, 25 to 50 years old, growing along 500 miles of streets. The number of requests for tree removals as the result of sewer lateral stoppage is overwhelming, sometimes as many as ten a day. We have removed a large number of trees in order to relieve this condition, but it is a physical impossibility to comply with even a small percentage of requests, and we do not like to remove otherwise fine trees. However, when the plumbers' bills mount up, the citizens demand action."

Space does not permit a complete review of all the interesting and revealing facts contributed by correspondents. Most cities revealed that the problem of root control was on an emergency basis. Prior to 1936, Ridgewood, N.J., was no exception, obstruction of sewer mains and house connections being all too frequent occurrences.

Foul odor conditions prevailed the year around at the sewage treatment plant, and concomitant disintegration of concrete structures had progressed to the extent that some structure walls were "razor backed" and were rebuilt by the Gunite method. Chlorine demand and costs were high and very poor results were being obtained from the biological oxidation process.

Chemical precipitation was a feature of the 1936 reconstruction program. Major difficulties encountered in operating this treatment process prompted a thorough investigation which ultimately revealed that the tree roots were primarily responsible and should be brought under control.

Copper sulfate (blue vitriol) is used extensively by the water treatment industry for the control and elimination of taste and odor producing microscopic organisms and undesirable aquatic plant growths.

Since efforts to dislodge the extensive growth of fungus in the sewer system by the application of chlorine had proved uneconomical and unsuccessful, the use of copper sulfate was next considered. Microscopic examinations showed Beggiatoa was the predominating species of fungus present.

Hale[2] indicated that a minimum concentration of 5 ppm. was necessary for the eradication of this species.

About two pounds medium size crystals were sprinkled along the exposed pipe inverts of intersection and terminal manholes throughout the sewer system, this work being performed from the street level. Two barrels (total 800 lb.) copper sulfate were thus applied to the system over a period of several days. Subsequent to this application some pipes were found literally full of the dislodged fungus growth being carried along in the flow. As a result of this preliminary treatment, odors were reduced to such extent that up-sewer chlorination was discontinued and the need for prechlorination at the plant for odor control, confined to a few summer months. Dislodged root masses were observed in the plant influent from time to time and stoppages in the sewer mains became less frequent.

The annual application of $CuSO_4$ to the system has been an established practice at Ridgewood, N.J., since 1937. A hand bill was prepared for distribution to residents, to pave the way for $CuSO_4$ work on the house connections from within the homes, since these pipes were found to be in worse condition than the mains in the streets.

Two or three pounds of crystals are applied through the commode and flushed outside the cellar soil pipe system. This program has been accelerated by the recent assignment of an employee to this work exclusively. Pre-chlorination for odor control is now unnecessary, even during summer months. Sewage is "fresher" and therefore more amenable to treatment by biological oxidation. This is reflected in improved effluent quality, despite increased population load on original trickling filter unit.

House Connections

Several connections whose outlets were available for sampling were selected from a sewer map. They were located in sandy terrain and it was not unexpected that the owners, when approached for permission to experiment, readily granted the desired permission and told of repeated sewer trouble and plumber bills.

The property owner was informed of our intention to use copper sulfate and it was specially emphasized that $CuSO_4$ had no magic qualities; that it merely had a toxic property capable of killing live roots which would in time break loose or disintegrate and be swept out by the flow of sewage. It was also emphasized that these root growths within the pipe were of 10-, 15-, 20-year standing; that we had no way in which to ascertain the extent of their infiltration and the amount of copper sulfate which would be necessary to kill them all.

Success crowned these efforts and a comparison of analyses made before and after the copper treatment showed that in all cases the pH-alkalinity equilibrium had declined. When subsequent determinations disclosed a calcium carbonate equilibrium more nearly resembling the city water, the connection was considered clear and no further treatment given.

Results Noted

A short street of seventeen homes having a bad record of sewer stoppage due to roots was next tackled. After several weeks the determination showed a decline in equilibrium from pH 7.9 and alkalinity of 435 ppm. to pH 7.7 and alkalinity of 227 parts. It is important to state that before the copper treatment of house connections in this street, the sewage was not responsive to any dose of chemical coagulant, whereas afterwards it was found to be amenable to chemical clarification with much smaller doses of chemicals than had been previously tried.

When a year had elapsed from the completion of work on this street, each connection was gone over with sewer cleaning equipment. All connections were found clean and clear, no roots being brought out by the equipment.

Since the extent of the root growth in any given pipe is unknown, a greater or lesser amount of the crystals may be required to permeate the whole mass.

An individual root mass entering at one point may clog a pipe or connection just as effectively as half a dozen, but obviously more crystals would be necessary for the greater quantity of roots.

Property owners and occupants furnish "case histories" by relating their woes with their sanitary connections, and the extent of the root growth may be deduced from their statements.

House Connections

As previously stated, crystals are applied through the commode within the home. The operator carries a container of crystals and puts two or three pounds through each connection. Where serious trouble and recurrent plumber visits have been experienced by the tenant, initial doses of six to ten pounds have been applied in an attempt to insure complete contact, and such cases have been marked down for repeat doses at weekly, fortnightly or monthly intervals, as the conditions seem to dictate. After the initial high dose, and in the absence of any further clogging troubles, normal low doses of crystals may be used.

When a connection is completely plugged and overflowing, rodding must be resorted to to restore flow through the root masses. Thereafter copper sulfate crystals may be applied, but not before. There has to be some flow through the connection in order to carry the solution down through the roots for the attack.

Street Sewer Mains

A light truck and a barrel of copper sulfate crystals are the operator's tools. Junction and terminal manholes are opened, a small scoopful of crystals are sprinkled along the invert of the pipe, and the manhole cover replaced. Thereafter the flow gradually dissolves the crystals and the resulting solution contacts roots and fungi as it flows down stream. About two pounds per manhole is applied, but here again this amount is increased as in the case of the house connections, when records indicate serious root trouble.

Under no circumstances should an amount of crystals sufficient to obstruct the flow be placed in the inverts, nor should crystals be placed in the traps of automatic siphon type flush tanks. In the first place, they will not dissolve due to the absence of flowing water, and secondly, they may tend to corrode the metal.

It is recommended that periods of normal to low flow be chosen to introduce the copper sulfate. Both the time of contact and the concentration of the solution are thereby enhanced. A preventative dosage may be given annually following the initial treatment. Old roots do not return, but new root infiltrations may develop.

Careful records of all work should be kept so that not only will the results be disclosed, but eventually all of the system and house connections may be serviced.

Some Important Dont's

Don't put $CuSO_4$ crystals in fixture traps. Corrosion by interchange of metallic ions will occur and eventually eat holes in the traps. Flush the crystals through the commodes when applying from within homes, and follow with a sufficient amount of flushing water to insure (1) their transit through the soil pipe to beyond the cellar wall and (2) their conveyance to and against the root obstruction, where the crystals will dissolve, discharging the solution slowly into the root mass.

Don't expect black magic properties from $CuSO_4$. Remember that a good root mass is well-nigh impervious to concentrated sulfuric acid. Only the life is taken by copper sulfate treatment and thereafter the normal processes of decay must ensue.

Don't waste $CuSO_4$ in the system during periods of high flow. The dilution factor is too great and the resulting concentration of the solution too weak to be effective. Pick low-flow periods.

Don't expect $CuSO_4$ to clean sewers and house connections mechanically obstructed by breakage, bad connections or faked bends. The amount used on a system in any given time should be arrived at by collaboration with the plant superintendent, who is best able to determine what the traffic will stand, by close observation of the biological and/or chemical processes incorporated in the plant.

References

(1) Fuller, G. W. "Sewage Disposal"
(2) Hale, Frank E. "The Use of Copper Sulphate in Control of Microscopic Organisms"

LOCATING LOST SEWERS AND MANHOLES*

By E. T. CRANCH
Director, Department of Public Works, New Rochelle, N. Y.

IF YOU have sewers, drains and manholes for which you have no records or for which available records are inaccurate, then, perhaps, some of the experiences recounted here may be of practical interest.

The settlement of New Rochelle, New York, was started in 1688, and it has enjoyed a consistent and rapid growth since then. It was incorporated as a village in 1858 and became a city in 1899. The 1940 federal census gives the population as 58,408. The area of the city is 10½ square miles.

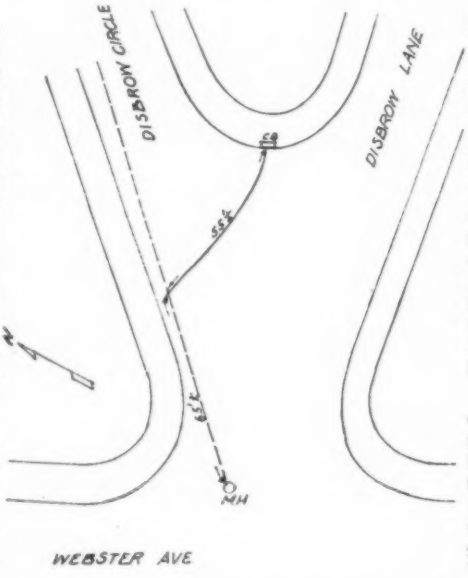
The population area of the city has largely expanded by individual real estate developments to which were assigned definite names, such as Residence Park, Halcyon Park, Highland Park, etc. In the early days, each real estate developer tried to be exclusive and laid out dead end streets. The streets were laid out with the definite intention of not connecting with the streets of any other development. Within recent years this situation has been corrected by the creation of a city planning board which has set up a master city plan, and every developer must have his plans approved by the planning board before he can start work; also, all plans for sewers and drains must now be approved by the Department of Public Works and the construction inspected by that department.

For many years, however, sewers and drains were installed by the developer under no city supervision; no maps were submitted to the city, and in some cases I have found the developer had no map showing the course of the pipe. I have found instances where the developer has laid pipes across lots, and when he sold the properties crossed by the pipe he retained no easement covering the repair or maintenance of the pipe.

I have found one instance where in 1894, by order of the Board of Health, the city laid a 15-inch drain meandering along the course of a brook across lots, filled in the bed of the brook over the pipe and never secured any easements from the property owners. A few years ago it became vitally necessary to increase part of this drain to 36 inches, and the city had to pay a substantial amount for the easement, although the 15-inch pipe had been occupying the same property for over forty years.

I have had occasion to investigate a situation where there were constantly recurring floods. I found a 24-inch vitrified tile drain completely plugged. From a point where an open brook entered this pipe, it was approximately 1,000 feet to the first manhole. The city had no plan of this drain. I contacted the developer and found he had no plan, but I took him to the location and he showed me, as well as he could remember, the course of the drain, which, it seemed, followed a reverse curve. The drain was laid with open joints, and went through a swampy area in which there were a number of willow trees.

This led me to believe that the stoppage was in all probability caused by the entrance of willow roots into the drain. This spot was too far away to be reached satisfactorily with flexible sewer rods from either opening in the drain. We therefore decided to put in a manhole in the swamp area. After four days of digging we finally located the drain at a depth of about 5 feet and opened it. We found the pipe completely filled with roots and it took almost two weeks of work to clear the line. This experience made me feel that there ought to be some means of locating underground sewers and drains.



Location of point of interscction of catch basin lateral and main drain simplificd by use of M-Scope at New Rochelle, N. Y.

I was familiar with the use of the M-Scope in locating underground water mains. So I asked the salesman to try it out on this drain with flexible sewer rods inserted in the drain. We got 238 feet of rods in the drain, placed the transmitter on the rod and also, by means of the wire and clip provided, connected it to the rod. With the receiving set we were able easily to follow the course of the curving drain for about 200 feet. At this distance the signal became rather faint, but one man with keen ears followed it for the full distance of 238 feet.

We then rigged up the transmitter and receiver on the carrying sticks and went over the line to see if by any chance we might find any hidden manholes. At one point, right over the line, we got a sharp signal and started to dig feverishly for the manhole, only to find that a steel barrel hoop was buried in the ground. However, this demonstration satisfied me that the instrument could be used satisfactorily, for the purpose of locating both tile drains or sewers and buried manhole covers.

At another time, to relieve a flood condition, we wanted to install a new catch basin in the middle of a block and connect it to an existing drain at a manhole shown on the map at about the point we wanted. There was, however, no evidence of the manhole on the ground. With the M-Scope we located the manhole within a few minutes, just off the paved area, and under about 3 inches of sod. This time it was really the manhole.

Another time the map showed a drain manhole on the east side of the street at a certain intersection. The M-Scope gave no signal on the east side of the street but gave a clear signal on the west side of the street and, sure enough, we found the manhole about 8 inches deep under the macadam pavement.

We had a sewer and a drain running through a private right-of-way. The map showed a manhole on each. The sewer and drain had been installed 14 years ago. For the past several years periodic efforts had been made to locate the manholes, but without success. This right-of-way had several angles in it. It passed through a fine estate and the property was so thickly landscaped with evergreens, paths, gardens, etc., it would have been almost impossible to have resurveyed the right-of-way without doing real damage to the property. With the M-Scope we located and uncovered both manholes within an hour. One manhole was covered with about a foot of dirt and the other with about 3 inches.

Another time we tried to follow the course of a drain, about 15 feet deep, which ran through territory covered with thick brush, so that it was impossible to follow the line directly from the manhole. The first open land was almost 200 feet away from the manhole and transmitter, but no signal whatever could be picked up there. We cut an opening in the brush about half way back, and were able to pick up the signal at that point. For deep drains it is necessary to limit the distance from the transmitter.

Another failure we had was in trying to find a couple of catch basins that we thought were located near an abandoned railroad bridge, where the land is thick with brush. Following along the gutter we picked up a signal on each side of the road and thought we had located the catch basins, but digging down we found nothing. I then found I could follow the signal across the road. There is a 24-inch drain at this point, installed by the old railroad company, and apparently 24-inch cast iron pipe was used to cross the road. This experience illustrated the fact that in locating catch basins or manholes, when a signal is picked up, it must be tested from every direction to see that it is not emanating from a pipe line.

In a road improvement job we had a 15-inch storm drain in the road and a catch basin on one side of the road with a lateral connecting to the drain at an unknown point. We wanted to install a new catch basin on the opposite side of the road, connect this basin to the drain at the same point as the lateral from the old catch basin and build a manhole at the junction of the three lines. The accompanying sketch illustrates the condition we faced. We ran the flexible rods through the lateral from the old catch basin and, much to our surprise, found that it followed a curved line. As a check for the point of intersection, we

*From *Sew. Wks. Jour.* 17, 199 (1945). Published here by permission of the Fed. Sew. Wks. Assns.

ran the rods up the 15-inch drain from the manhole at Webster Avenue and located it on the ground. At the indicated point of intersection we dug down and found ourselves at the exact point desired. If we had simply assumed that the original lateral had been laid on a straight line as it should have been, we would have dug for days before we would have found the right spot.

We have also used the M-Scope to trace the meandering drain laid in 1894 and mentioned at the beginning of this paper. Here the instrument proved very effective and also located two manholes which had long been covered along its course.

In conclusion, I will say that I have found the M-Scope very effective for locating the position of shallow drains for distances of about 200 feet, and for deep drains about half that distance. It is excellent for locating manholes as long as care is used in its operation, and it is understood that it will pick up any metallic substance underground, be it manhole, barrel hoop or pipe line.

RESULTS OF EFFLUENT CHLORINATION AT CLEVELAND

By JOHN J. WIRTS

Superintendent, Easterly Sewage Treatment Plant, Cleveland, Ohio

DURING each summer, a bacteriological and microscopic analysis of water from seven bathing beaches on Lake Erie adjacent to the Easterly Sewage Treatment Plant of Cleveland, Ohio, is conducted as part of the regular laboratory routine.

Table 1 shows the combined yearly average figures and per cent reduction of total bacteria and Coliform Bacteria, expressed as the Most Probable Number per ml., for the six beaches from East 140th to East 185th Street. The median figures in the table are the arithmetical averages of the yearly medians for the six beaches.

These six beaches were combined into one table because they all showed similar results, and because they are all affected by the Easterly Plant effluent. From the outfall, which empties at lake level beyond a breakwall about 1,000 feet from the shoreline, the lake current and the prevailing winds normally carry the effluent in an easterly direction, after considerable diffusion. It can be stated with a reasonable degree of certainty that the very great improvement in the bacterial quality of the East shore waters is due solely to the efficient operation of Easterly Sewage Treatment Plant and consistent chlorination of the effluent.

During the summers the effluent is chlorinated sufficiently to maintain a residual of from 0.5 to 1.5 ppm. The total bacteria count in the chlorinated effluent averages about 50 and the Coliform Bacteria are always zero.

TABLE 3
QUALITY OF WATER IN EFFLUENT STREAM IN LAKE
(JULY 21, 1941)

Sample No.	1	2	3	4	5	6	7	8	9	10
Percent effl. in sample (1)	89	28.	43	30	26	26	23	4	26	26
Residual chlorine	0.1	0.2	0.3	0.15	0.15	0.1	0.05	Tr.	0.15	0.15
Total bacteria per ml.	132	79	15	34	36	31	43	61	45	19
Coliform bacteria per ml.	0	0	0	0	0	0	0	0	0	0
Coliform bacteria per ml. (MPN)	13.0	1.7	0.8	0.8	1.7	0.9	1.7	1.7	0.8	0.8

TABLE 4
QUALITY OF WATER IN EFFLUENT STREAM IN LAKE
(AUGUST 29, 1941)

Sample No.	1	2	3	4	5	6	7	8	9	10.
Percent effl. in sample	100	48	21	20	14	14	13	16	16	14
Residual chlorine	1.0	0.25	0.25	0.25	0.25	0.25	0.25	0.3	0.2	0.2
Total bacteria per ml.	13	42	26	27	21	18	26	20	25	23
Coliform bacteria per ml.	0	0	0	0	0	0	0	0	0	0
Coliform bacteria per ml. (MPN)	0.8	1.7	0.8	0.8	0.8	0.8	0.8	1.7	0.8	0.8

Note: Total count—Agar 37½°.
(MPN) = Most probable numbers.

Quality of Lake Water in the Effluent Stream

During 1941, three series of ten samples each, taken at various points, 100 feet apart, in the effluent stream in the lake, were analyzed bacterially and chemically. The accompanying tables 2, 3, 4 show the results.

The figures for percent effluent in the samples were arrived at as follows: The chlorides were determined on one series of twenty-four samples of lake water at various points along the shore and the breakwall, and at other points from 100 to 1,000 feet from shore, all points distinctly outside the effluent stream. The average of these determinations was taken as the chloride content of the lake water for all three series of tests. The chloride in the effluent at the time of sampling was known. The chloride on each of the ten samples was determined. Then, by a simple calculation, the percent effluent and lake water in the samples was determined.

These tests showed that the effluent was not only much cleaner than shore water of the lake, but, due to long-lasting chlorine residual, was having a pronounced sterilizing effect on the adjacent lake water. This effect was reflected in the surveys of water quality along the beaches.

In calm weather, the effluent stream flows north for about 400 feet and then diffuses over a large area. The general direction of flow after that is toward the east.

In the three years the plant has been operating a 91 per cent reduction in pollution of the bathing beach waters has been effected. Although the lake is receiving a certain amount of polluted water from several small streams the bacterial content of the beach waters is within the upper limits of that recommended by the City of New York for bathing waters.

Ordinarily one would assume that every state would have a definite set of standards for shore bathing waters, similar to those of New York and Connecticut. However, at the time of the preparation of this report, Ohio did not have any published standards.

TABLE 1
BACTERIOLOGICAL STUDIES OF WATER FROM SIX BATHING BEACHES—CLEVELAND, OHIO

	Yearly Averages				Percent Improvement Over 1938		
Year	1938*	1939	1940	1941	1939	1940	1941
Total bacteria per ml. 37½°							
Average	30,000*	2800	3500	2400	91	88	92
Median	16,000	1600	3000	1900	90	81	88
Coliform bacteria per ml., M.P.N.							
Average	744*	148	94	73	80	87	90
Median	200	30	30	29	85	85	86

*1938 samples taken before Easterly Plant was in full operation.

TABLE 2
QUALITY OF WATER IN EFFLUENT STREAM IN LAKE
(JUNE 30, 1941)

Sample No.	1	2	3	4	5	6	7	8	9	10
Percent effl. in sample	38	38	5	1	7	7	2	2	0	7
Residual chlorine	0.2	0.2	0.1	0.1	0.1	Tr.	Tr.	Tr.	0	Tr.
Total bacteria per ml.	33	11	6	15	10	175	13	7	90	9
Coliform bacteria per ml.	1	0	0	0	0	0	0	0	0	0
Coliform bacteria per ml. (MPN)	24.0	0.8	1.7	0.8	0.8	1.7	0.8	0.8	6.0	0.8

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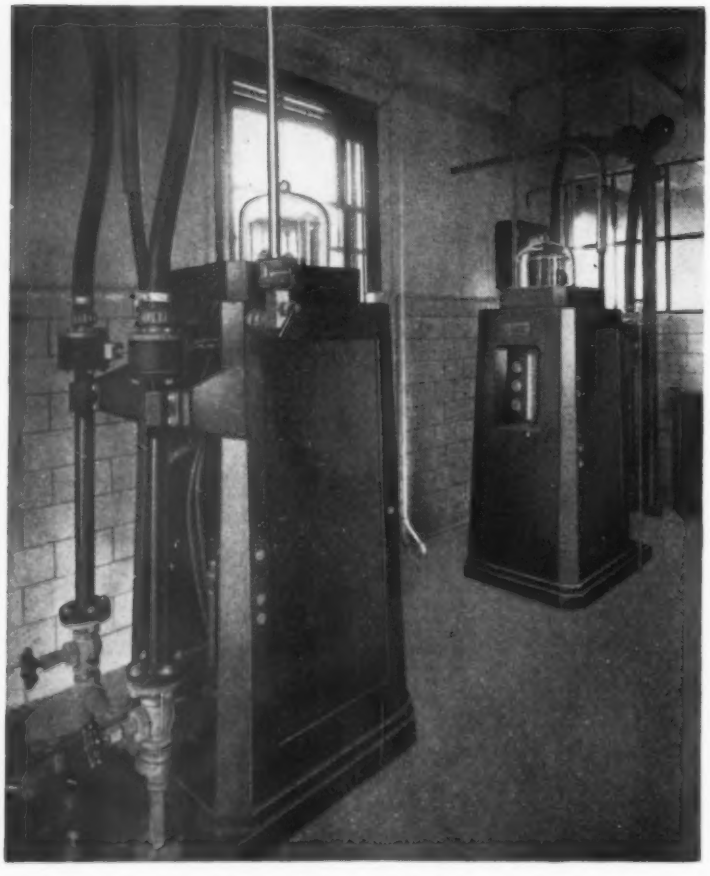
DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



W&T Master Automatic Visible Vacuum Chlorinators. Stamford, Connecticut, Sewage Treatment Plant.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

EQUIPMENT

For every sewage plant, there is W&T Equipment to fit. Visible Vacuum Chlorinators with capacities from ounces to 6000 pounds per day—Solution Feed and Direct Feed Chlorinators for small plants—and Reagent and Chemical Feeders to meet many varied chemical treating applications. All W&T Apparatus is backed by over thirty years' experience and is job-engineered by chlorination specialists.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any specific sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.

CHLORINATION OF SEWAGE*

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MANY papers have been written on the chlorination of sewage, and quite often under this same general heading. All have agreed that the primary use of chlorine in sewage treatment is for disinfection. Most have mentioned several other uses of chlorine. Few have emphasized, uder a single heading, these other uses of chlorine to any level of practicability. In an operational paper such as is intended here, the latter is essential. Almost every chlorine use in a treatment plant, other than disinfection, is for the purpose of solving some particular problem confronting the superintendent or operator.

An admirable basis for a classification of the uses of chlorine in sewage treatment is found in a recent article by Enslow and Symons [1]. They state that by definition there are only three processes of sewage treatment, namely, primary treatment, secondary treatment, and disinfection. Sludge disposal is merely a byproduct process.

To apply chlorine to this classification is a simple matter. Chlorine in sewage treatment for disinfection stands alone. Most of the other uses of chlorine in sewage treatment deal with its application for solving trouble with, or benefiting, the other two processes. From an operational viewpoint, it is with these processes, and the use of any chemical as an adjunct thereto, that the superintendent and operator are fundamentally and vitally concerned.

Development of the Use of Chlorine

The growth of chlorination in sewage treatment is contained in a 1946 survey [2] of sewage plants. Of a total of some 5,400 sewage plants, 1,320 were found to be using chlorine for one purpose or another. This represents a 30 per cent increase in the number of plants using chlorination in the last eight years. This growth can be attributed, to a large extent, to the use of chlorine for disinfection in the slightly more than 1,000 sewage plants built during the war period. This growth is also due, without doubt, to the continued expansion in the use of chlorine as an adjunct of primary and secondary treatment. Odor control uses are among the most significant.

Of 297 sewage plants in Pennsylvania, 139 were found to be using chlorine. Pennsylvania has the same number as New Jersey, and both are exceeded only by New York state, with 172 plants using chlorine. In the percentage of plants using chlorine, Pennsylvania with 46.5 per cent ranks fourth, being exceeded only by New York with 52 per cent, Louisiana with 51.8 per cent, and New Jersey with 51.1 per cent.

Chlorine for Disinfection

History

Chlorine was first used for the disinfection of sewage at Hamburg, Germany, in 1893. The first recorded use of chlorine for this purpose in the United States was a year later, at Brewster, N. Y., where A. E. Woolf obtained chlorine in the form of sodium hypochlorite by electrolyzing a strong brine solution. This hypochlorite was applied to the sewage for disinfection purposes to protect the Croton Reservoir water supply of New York City.

In 1906 and 1907, Phelps, with the aid of others, studied the use of chlorine for the disinfection of sewage at Boston, Baltimore, and Red Bank. The use of chlorinated lime at the latter plant, by Phelps and Daniels, marked the real beginning of chlorination for sewage disinfection in the United States.

After liquid chlorine came into use in 1914 for the disinfection of sewage at Altoona and Milwaukee, its use at other plants followed in rapid order. Soon the United States obtained a lead never relinquished. Today, more plants in the United States use chlorine for sewage disinfection, or for that matter for any other purpose, than anywhere else in the world.

In the fewest possible words, the purpose of chlorination for sewage disinfection is to prevent bacterial contamination of (1) streams or other receiving bodies of water used for public water supplies, (2) the shell-fish industry, and (3) recreational areas such as those used for bathing.

Application Points

From an operational standpoint, it is important to mention that Tiedeman and Enslow established that when a high degree of disinfection (effective disinfection) was needed, it was necessary to maintain a slight chlorine residual after a contact or detention period.

If primary treatment is the only treatment process at the sewage plant, the proper detention period for disinfection can best be afforded by prechlorination ahead of the settling basin. Occasionally, postchlorination of the settling basin effluent ahead of a long outfall sewer will afford the proper contact time.

If secondary treatment is used at the sewage plant, the proper detention period can be obtained by postchlorination ahead of the final settling basin, ahead of a chlorine contact chamber, or ahead of a long outfall sewer.

Residual Requirements

As a rule, the amount of chlorine residual that must be present in the sewage after a given contact period in any of the treatment units mentioned above depends upon the local state health department requirements. Whatever the regulations, the superintendent or operator should be aware of them and see that they are followed as rigidly as is practically possible. State board of health requirements appear to cover the range of 0.2 ppm. chlorine residual after a 5-min. contact period to 1.0 ppm. chlorine residual after a 30-min. contact period. On the average this requirement is not far from a 0.50 ppm. chlorine residual after a 15-min. contact period.

Dosage Requirements

The amount of chlorine required for sewage disinfection will depend upon several factors, including the state health department requirements. Compliance with a certain chlorine residual after a given contact period is merely satisfaction of the chlorine demand of the sewage. The one important factor, therefore, is the chlorine demand of the particular raw or treated sewage to be disinfected. For raw sewage the amount of chlorine required for disinfection usually varies from 10 to 20 ppm. For highly septic raw sewages this figure can be as much as 40 ppm. The chlorine requirements for disinfection of secondary treatment effluents vary from 6 to 12 ppm. for trickling filters, 3 to 6 ppm. for sand filters, and 2 to 4 ppm. for activated sludge plant effluents.

During sewage disinfection studies at Buffalo, Symons, Terhoeven, and Torrey [4] found that the chlorine required for adequate disinfection of a raw domestic sewage was 0.005 lb. of chlorine per capita per day. At one Pennsylvania sewage plant employing prechlorination ahead of settling for disinfection and receiving a fresh, strictly domestic sewage, the figure was 0.006 lb. of chlorine per capita per day. When industrial wastes are present the figure will be higher. In actual plant operation at Buffalo, the figure, as a result of industrial wastes in the sewage, increased to 0.010 lb. of chlorine per capita per day. Whether industrial wastes are present or not, these figures may in time prove to be a reliable estimation of the chlorine requirements for disinfection.

Dosage Control

Control of chlorination for disinfection consists usually of checking chlorine residuals with the ortho-tolidine or the thiosulfate starch-iodide test, and then resetting the manually controlled chlorinator when indicated. Automatic solution feed type chlorinators are used to a limited degree in sewage treatment. The latest development, and one more applicable in all respects, consists of a program chlorinator which permits the application of chlorine to more nearly conform with the changing total chlorine requirements caused by changes in volume and chlorine demand. The program arrangement permits adjusting the chlorine applications each hour.

The number of residual determinations and resettings of a manual chlorinator required daily depends upon the size of the sewage plant. In the large plants where economy is an item, accurate control is essential. Whatever the frequency of control tests and chlorinator adjustments may be, they must be adequate to maintain not less than the required chlorine residual at all times.

At small plants proper control may be provided by determining the chlorine residual once a day, at the time when the maximum chlorine requirements may be expected, and then resetting the chlorinator as the test indicates. If the chlorinator is reset, another chlorine residual should be taken after the proper lapse of contact time. Both chlorine residuals, not just the last, should be reported on the daily log. Based on experience, it is advisable to have two regular chlorinator settings—one for the day flow and one for the night flow.

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At larger plants the chlorine residuals should be taken every hour or every two hours during the daytime. Chlorinator resettings should be made frequently. A curve showing poundage of chlorine per unit volume of sewage flow versus time for the daytime hours for each day of the week is of inestimable value in arriving at the proper chlorinator settings throughout the day. Often a set of figures in lieu of the curve serves equally well, for then it is an easy matter to readjust the figures for use during the following week.

This practice was adopted at one Pennsylvania sewage plant. Prior to the use of daily chlorine poundage cards, 10 per cent of all of the chlorine residuals taken hourly between 8:00 A.M. and 5:00 P.M. were zero. After the card system was put into effect, only 4 per cent of the chlorine residuals taken hourly were zero.

At the largest plants where the personnel is adequate and well equipped laboratories are available, the control of chlorination is considerably more accurate. For example, at both Buffalo and Los Angeles close checks on the chlorine dosages are maintained by taking hourly chlorine demand tests.

Chlorine as Adjunct to Primary Treatment

Odor Control

Odors were a problem in sewers and receiving streams long before they were ever thought of as a problem at sewage treatment plants. In 1777 sewer gases in Paris caused several deaths. In 1806, some 29 years later, a committee came to the conclusion that these deaths had been due to hydrogen sulfide.

Several decades later, the Royal Sewage Commission of Great Britain recommended that the London sewage be chlorinated for odor control by using bleaching powder. Dibden put this recommendation into effect in 1884. Thus, by this event chlorine compounds came to be used for odor control before they were used on a practical basis for disinfection.

In 1912, Ellms and Waring of Ohio tried chlorinated lime for odor control on a septic tank in Cincinnati. Cleveland became one of the first cities to chlorinate sewage in an outfall sewer for the purpose of controlling odors. With the advent of the Imhoff tank the use of chlorine for odor control received considerable impetus. By 1930 [6], 50 plants in the United States were listed as using chlorine for odor control. Since then, the number of plants using chlorine for this purpose has expanded rapidly.

In this country the control of odors today is usually the number one problem of sewage works superintendents and operators. There are odors at every plant but the degree of their intrusiveness and obnoxiousness varies widely. The problem has been more acute in recent years with the tendency to situate sewage plants nearer cities and towns and along the main arteries of travel. An example of this is the location of a sewage plant on Long Island. There, 30 cottages are located within 1 to 25 ft. of the plant site. As the sewage plants become more critically located, the number of odor complaints is bound to increase. It is the responsibility of the superintendents and operators to satisfy all legitimate complaints and develop good will. Lawsuits are costly.

The purpose of odor control is to prevent odors from forming or reduce those already present below a level objectionable to the population. Many compounds in sewage, including such derivatives as indole and skatole, cause odors at sewage plants. By far the most serious odors are those of hydrogen sulfide. It has been said that one can detect hydrogen sulfide in air in concentrations as low as 0.000001 ppm., but experience has amply shown that 0.8 to 1.0 ppm. can be present in sewage settling basins without causing complaints.

From an operational standpoint, it is important to mention that Heukelekian [7] showed the chlorine application for effective odor control to be definitely related to the chlorine demand of the sewage and the degree of hydrogen sulfide production. The author found that a minimum of 20 to 25 per cent of the chlorine demand of the sewage should be satisfied in order to keep the sulfide content below 1.0 ppm. for a reasonable period. In practice it has been necessary, in some instances, to satisfy as much as 50 per cent, or slightly more, of the chlorine demand to obtain effective odor control. Hydrogen sulfide theoretically takes 2.22 ppm. of chlorine for each ppm. of sulfide. In practice, 3 to 15 ppm. of chlorine has been found necessary for the destruction of each ppm. of sulfide due to the immediate demand of other compounds in the sewage for the chlorine.

A recent and rather comprehensive article [8] on the subject of hydrogen sulfide formation is mentioned because it has a direct bearing on the operational angle of odor control. It appears that hydrogen sulfide formation is not particularly dependent upon the age of the sewage or the sulfate concentration of the sewage. Hydrogen sulfide production increases with increasing temperature, with increasing strength of the sewage, with decreasing pH of the sewage, and with decreasing velocity of flow. It is important to note in this instance that the hydrogen sulfide came from the slimes on submerged surfaces of the sewers and from deposited sludges in the sewers. On this hypothesis, odor control becomes a question of slime control.

If odors are present in the sewage on its arrival at the sewage plant, the sewage should be chlorinated, if at all possible, at a distant pumping station, trunk sewer, or interceptor. At some plants it is structurally possible to chlorinate only at the plant, as prechlorination ahead of settling.

The importance of up-sewer chlorination cannot be overemphasized. Up-sewer treatment has the advantage of preventing sewer deterioration due to sulfuric acid formation. Disintegration of concrete conduits and mortar joints can prove costly. Considering odor control as slime control, the advantage of up-sewer chlorination becomes obvious. Besides any other consideration that might be given to the sewers, up-sewer chlorination is preferable to prechlorination at a plant receiving sewage with hydrogen sulfide odors. Prevention is more economical than removal.

If the sewage is rather fresh on arrival at the plant and it is definitely established that the odors are being produced in the primary treatment units, Imhoff tanks being a recognized offender, then prechlorination at the plant as prevention control should be practiced. In such cases it is advisable to apply the chlorine, if practical, ahead of the screens or the grit chamber to obtain overall odor control in the primary units.

Chlorine for odor control is usually fed seasonally or continuously, depending upon local conditions. Control is obtained by applying enough chlorine to satisfy 25 to 50 per cent of the chlorine demand. This means 25 to 50 per cent of the amount of chlorine required for sewage disinfection. For prevention control, less chlorine will be required than for removal control because the latter is often coincident with a highly septic sewage.

When up-sewer chlorination for odor control is to be considered as slime control, it may be advisable to destroy the sulfides completely. Under such circumstances the chlorine requirements will be the 3 to 15 ppm. of chlorine for each ppm. of sulfide, as stated above. However, the chlorine needed will be less than that required to satisfy the chlorine demand.

The control of the amount of chlorine that must be used for effective odor control is more difficult than the control of sewage disinfection due to the fact that there is no chlorine residual to chlorinate to. The actual amount of chlorine that has to be used can be determined satisfactorily at plants having well-equipped laboratories by making frequent or occasional sulfide tests. Such tests show if the sulfide is being held below the maximum allowable limit of 0.8 to 1.0 ppm. A modified methylene blue test [9] has been successfully used for the control of odor. Lacking either test, and this is commonly the practice in the small plants as well as many larger ones, the number of complaints received is the criterion of adequate control.

This brings to mind the story [10] of Homer Fisher at Benton, Illinois. He keeps grimacing into a mirror. He has several silver fillings in his teeth. When the fillings turn black, he then knows it is time to start prechlorination for odor control. This brings to attention an important fact. Odor control regulated by smell alone is an unsatisfactory method of control. The nose soon becomes insensitive to the continued presence of hydrogen sulfide.

Effective odor control can also be obtained by the use of iron salts made by treating scrap iron with chlorine. It is an economical method, particularly when the sulfide content of the sewage is extremely high or when a highly septic sewage is encountered. Mixtures of ferrous and ferric iron are reported to be more effective than either alone. They appear to be most effective when the solution contains about two-thirds ferric iron salts.

Plant Overload

Overload may be due to exceeding the designed capacity of the plant, to the presence of industrial wastes in the sewage, or to the return of too much supernatant overflow to the raw sewage. The first is volume overload, the latter two are organic overloads. All three are related to B.O.D.

Chlorination of sewage for any purpose reduces the B.O.D. and hence the load on the plant. When up-sewer or prechlorination is used for odor control, the load on the plant will be less because the B.O.D. is being reduced at the same time. When prechlorination ahead of settling is being used for disinfection, the load on the primary and secondary units will be

less, because chlorination has been carried still further and the B.O.D. reduced still more. Obviously, there is a limit to correction with chlorine when volume overload reaches a certain critical point.

In using prechlorination for reducing plant overload, each ppm. of chlorine will reduce [11] the B.O.D. approximately 2 ppm., *i.e.*, for each pound of chlorine applied, the B.O.D. will be reduced by about 2 pounds. This rate of reduction is fairly constant up to the point where a chlorine residual, as in sewage disinfection, is obtained. By the time the chlorine is added in sufficient amount to produce this residual, the B.O.D. load on the plant is reduced by 15 to 35 per cent. This reduction is most significant with strong sewages, highly septic sewages, sewages containing industrial wastes, and when supernatant is being returned to the raw sewage. It is uneconomical to chlorinate beyond the point necessary to obtain a chlorine residual. Beyond that point the amount of chlorine required to give a comparable B.O.D. reduction becomes excessive.

The use of prechlorination for reducing plant overloads has often exceeded expectations. One of the most outstanding instances is that reported by Rawn [12] several years ago. Septic sewage was reaching an activated sludge plant and as a result the sewage would not respond readily to secondary treatment. Chlorination of the raw sewage produced a fresh sewage at the plant and its capacity was thereby trebled.

At Butler, Pa., Haseltine reported [13] how changing from postchlorination at the primary units to prechlorination produced greater B.O.D. removal through one clarifier than previously was obtained through the use of two clarifiers in series.

Grease Removal

Grease is a problem at many sewage plants. Mahlie [16] says that grease occurs in sewage in larger quantities than is usually suspected and that its effects are more far reaching than is admitted.

Gascoigne [17] as early as 1931 reported that chlorine applied to sewages or industrial wastes high in grease would break up the emulsions allowing the grease to float, thus facilitating its collection. Superintendents and operators have noted this for years and on rare occasions have reported their observations. Most of the observations have followed the same general pattern. Prechlorination was found to increase the amount of scum removed from the surface of the settling tanks. It did not result in more frequent skimming. Actually the scum appeared to accumulate in a more dense or compact mass requiring less skimming and resulting in an improved general appearance of the settling basins and clarifiers.

In 1937, Faber [11] reported the first use of chlorine with diffused air, a process called aero-chlorination, at Woonsocket, R. I. Wiest [18], in 1938 at Lancaster, Pa., modified the procedure by applying chlorine solution to the sewage ahead of the aerators.

The reasons for which grease may be removed, partly as scum and partly as sludge from various settling processes, are several fold. The number of adverse effects it may have on sewage plants has been ably listed by Mahlie [16]. It blinds screens, accumulates on walls, destroys the paint on steel structures, gives rise to odors, interferes with Imhoff tank performance, interferes with secondary treatment, clogs filters, and interferes with sludge digestion.

Chlorine for grease removal can be applied as prechlorination ahead of a preliminary skimming tank, ahead of a settling tank, or ahead of aeration tanks. Aero-chlorination may also be employed in which case dry chlorine gas is mixed with the diffused air going to the aeration tanks.

If chlorine is applied to the sewage as prechlorination, it is not necessary to chlorinate to a residual to obtain further removal of the grease. Often as little as 2 to 5 ppm. of chlorine will suffice.

If aero-chlorination is employed, it is general practice to use 2 to 10 ppm. of chlorine as chlorine gas and 0.02 to 0.20 cu. ft. of air per gal. of sewage, with a 3 to 20-min. aeration period.

Improved Clarification

When prechlorination has been used for disinfection, odor control, plant overload, or grease removal, many superintendents and operators have found considerable improvement in the clarification of the primary tank effluents.

Cohen [18], in 1928, was among the first to report on this effect. At the Lufkin, Texas plant, prechlorination ahead of the Imhoff tank resulted in a tank effluent containing less suspended matter. Others have reported the same effect. In recent years, the use of prechlorination has been reported to have improved the settling rate at the sewage plants at Annapolis, Md., Clearwater, Fla., Kankakee, Ill., and Racine, Wis.

The purposes of using chlorine for improved clarification are (1) to improve the settling rate of normal sewages, (2) to overcome the septicity of raw sewage and thus keep the sludge from rising in the clarifier, (3) to increase grease removal and thus overcome the adverse settling effect grease has on the suspended matter, and (4) to aid in chemical precipitation processes.

As regards the rising of sludge in clarifiers, Jones (19) in a recent article points out that septic sewage and industrial wastes are the worst offenders. The buoyant effect of suspended solids containing gaseous decomposition products causes the solids to rise, or at least retards their settling rates, so that the solids are carried out in the effluent.

Prechlorination applications of as little as 1 ppm. of chlorine will increase the settling rate of a normal sewage, and for septic sewages as little as a 2 ppm. application has given some improvement. When industrial wastes are present and are adversely affecting the settling rate, considerably higher applications of chlorine are required. The amount depends upon the particular wastes involved and may be several ppm.

The use of chlorine as an aid to coagulation or chemical precipitation is not confined to sewage treatment alone. Prechlorination has been of aid to coagulation in water treatment for many years. At Butler, Pa., Haseltine [20] found that the addition of chlorine was a necessary adjunct to chemical coagulation of sewage when using iron salts. The same observation is on record at the Shades Valley plant at Birmingham, Ala.

Decreasing Load on Stream

The primary purpose of a sewage treatment plant is to lower the B.O.D. and bacteriological load delivered to the receiving stream.

The use of chlorine for relieving the load on the stream is particularly applicable at sewage plants employing only primary treatment. It is a desirable adjunct with primary treatment at those times of the year when stream flows are insufficient to give proper dilution. It should not be inferred from this, however, that chlorination for this purpose is by any means a substitute for secondary treatment.

The most common practice for decreasing the load on the receiving stream appears to be prechlorination ahead of settling, in which case the B.O.D. is reduced as mentioned under the subject of plant overload.

Postchlorination of the primary effluents is not excluded as a use of chlorine for this purpose. It has been used with considerable success, and B.O.D. reductions of as much as 50 per cent have been reported, although with primary effluents the reduction normally is not expected to exceed 25 to 35 per cent.

Chlorination sufficient to produce a residual at the point where the sewage effluent enters the stream is usually advisable. The report of the A.P.H.A. Committee on Sewage Disposal [11] states that chlorination sufficient to produce a chlorine residual in the stream receiving the chlorinated sewage or effluent will retard the normal decomposition processes and will tend to prevent anaerobic conditions during normally critical periods of rapid oxygen depletion. It permits an opportunity for reaeration and additional dilution from tributary streams to maintain aerobic conditions. The committee warns, however, that the effect of chlorine carried in sewage effluents may be negligible in streams containing extensive sludge deposits.

Other than reduction in the B.O.D. load on streams, the reduction in the bacterial load is of utmost importance. The primary treatment plants at Buffalo and Detroit are the largest plants in the United States using chlorine for this purpose. Both use prechlorination.

These plants are correctly interested in keeping the number of bacteria in the sewage effluent down to a certain specific level. Unfortunately, most bacteriological results obtained at sewage plants have been reported as percentage of bacteria removed within the plant rather than the number of bacteria remaining in the effluent. It cannot be overemphasized that it is the number of bacteria per unit volume of sewage discharge to a stream and not the percentage of bacterial reduction in the plant which determines the quality of the receiving stream.

Chlorine as Adjunct to Secondary Treatment

Trickling Filter Odor Control

Odors have always been a problem in the operation of trickling filters. For one reason or another, the odors from trickling filters appear to be more offensive to a citizen than the odors from primary units. It appears that there have been more damage suits resulting from trickling filter odors than from those of primary treatment units. At least one city in the United States has had as many

as 25 to 30 lawsuits as a result of odors from trickling filters.

In 1911 [31] bleaching powder was used at Stratford-on-Avon in England for controlling odors at trickling filters. Three years later this plant moved the point of application to the crude sewage and thereby was able to eliminate odors throughout the plant.

Enslow, of the Chlorine Institute, in the late twenties and early thirties was particularly active in giving assistance to plant superintendents and operators in eliminating odor problems at sewage plants, including the odors at trickling filters.

Cohn [22,23], at Schenectady, was one of the first plant superintendents in the country to experiment with the use of chlorine for controlling odors at trickling filters. Washington, N.J. [24] was among the earliest plants to apply chlorine at the dosing tank for odor control at the trickling filters.

The object of using chlorine for odor control at trickling filters is to eliminate the nuisance of odorous gases released from the spray and, occasionally, from the filters.

Chlorine for the control of odors at trickling filters is fed seasonally or continuously, depending upon plant conditions and the proximity of the plant to nearby residences or highways. Two procedures in the application of chlorine appear to be acceptable. The chlorine may be applied either as prechlorination ahead of the settling tanks or as primary treatment postchlorination to the primary effluent on its passage to the dosing tank.

Control usually is obtained by applying enough chlorine to satisfy 10 to 20 per cent of the chlorine demand. In a few cases as much as 100 per cent of the chlorine demand must be satisfied. The amount of chlorine required at most plants seems to vary from 2 to 6 ppm., the quantity naturally being dependent to some extent on whether the chlorine is being applied to the primary tank influent or effluent. Recirculating part of the plant effluent is sometimes an effective way of reducing the chlorine requirements.

As mentioned previously, the control of chlorination when not chlorinating to a residual is often more difficult than in those cases where a residual is required. The most common criterion of the proper amount of chlorine to be used is the number of complaints received. Some plants do not like to rely on this type of control, because, if something goes amiss, a considerable amount of good will can be lost.

Some plant superintendents or operators have effected control by adding sufficient chlorine to the primary effluent to produce either a small chlorine residual or a small amount of dissolved oxygen in the sewage at the spray nozzle or distributor.

When the odor nuisance is from the filter itself, chlorination of the sewage has not always been effective, particularly where spray nozzles are used, due to incomplete coverage of the filter surface. In such cases, spreading chlorinated lime or hypochlorite over the surface has been extremely effective. Hirsch [35], in a recent article, reports that an application of about 10 lb. of dry hypochlorite per 1,000 sq. ft. of filter area is quite satisfactory.

At Lebanon, Pa., Beamsderfer [28] applies 2 ppm. of chlorine to the Imhoff tank effluent for odor control at the trickling filters. He occasionally makes a dissolved oxygen test. When he finds none, he starts recirculation of the secondary effluent. This procedure has resulted in very effective trickling filter odor control.

Filter Pooling Control

Filter ponding or pooling has been experienced at several trickling filter plants. Many superintendents and operators consider this an embarrassing situation and more so when they have to resort to a drastic chlorination practice. At some plants this pooling occurs regularly in the late winter or early spring. Others fortunately have never had this trouble, but since it may occur unexpectedly at any time, it is well for superintendents and operators to be acquainted with the steps that should be taken for its correction.

The purpose of using chlorine for the relief of a ponded filter is to remove the clogging, which is usually in the upper 8 to 16 in. of the filter, due to sewage solids, organic growths and, at times, algae.

Filter ponding is controlled by measures that may be described as removal or prevention.

Control by removal is afforded by chlorination in two ways: (1) by applying chlorinated lime or dry hypochlorite on the surface of the filter, or (2) by chlorinating the filter influent. If chlorination is resorted to, it should be applied at night when the chlorine demand and flow of the influent are at their lowest. An adequate chlorine residual, the secret of effective relief, is thus obtained at a considerable saving in chlorine.

The amount of chlorine required for the relief of filter pooling is usually expressed as ppm. of chlorine applied, or as lb. of chlorine per 1,000 sq. ft. of filter area. If hypochlorite is used, the application required will likely be about 8 to 12 lb. of available chlorine per 1,000 sq. ft. of filter. If the influent to the filters is chlorinated, the amount of chlorine required must be sufficient to give a 2 to 10 ppm. chlorine residual at the nozzle. This may require anywhere from 5 to 30 or 40 ppm. of chlorine. Whatever the practice may be, chlorination is continued nightly until the filter ponding has been relieved. It may take 2 to 6 successive nights before the relief is complete.

Control by prevention is usually practiced at those plants periodically plagued with filter pooling. To insure permanent relief, many of these plants have set up a chlorination program which experience has proven to be highly beneficial. Chlorine is sometimes applied to the filter influent continuously or semicontinuously in moderate doses. Chlorination may be programmed so that it is applied 1 day a week at 2-hour intervals or 1 night a week from possibly 8:00 p.m. to 8:00 a.m., or any other combination. If such a programmed procedure is followed, the dose should be moderate but sufficient to maintain a 1 to 2 ppm. chlorine residual at the nozzle.

In the control of filter ponding, it is sometimes necessary to take extremely drastic action. Although not recommended, the case at Westfield, N.Y. [27] can be cited. To get rid of the ponds on the filter, it was found necessary to run the chlorinator hose to the filter and spray the chlorine water directly on the surface of the filters with the chlorinator running at its full capacity of 200 lb. per day. The treatment inactivated the filter for about 5 weeks. Under more normal treatment the filter effluent is usually of satisfactory quality in a week or so after the ponding is relieved. Many plant reports show that the effluent, in returning to normal, is of far better quality than it had been for months previous to the ponding.

At Butler, Pa. [25], heavy chlorination of the final settling tank effluent and recirculation of this effluent would not, under normal operation, relieve a filter ponding condition. Ponding was finally eliminated by pumping chlorinated effluent to the filter influent and having an operator hold the distributor arm in one place for about 30 min., then rotate the arm 10 ft., and repeat the performance until the filter had been completely treated in this manner.

Filter Fly Control

Psychoda alternata are a nuisance at many trickling filter plants, particularly to the plant personnel. Prevention of the nuisance is preferable to trying to reduce the number of the flies after the situation has become almost unbearable. It must be admitted that this is not as simple as it sounds.

Many plant superintendents and operators do not like to use chlorine for this purpose for fear that such chlorination will harm the operation of the filter. Yet, if chlorination is adequate to remove some of the organic growths in the upper layer of the filter, it is reasonable that the breeding ground for the psychoda fly will have been considerably minimized.

In controlling the filter fly, chlorine is applied to the filter only during the fly season. Chlorination is programmed during night flows when the amount of chlorine required to obtain a chlorine residual is at a minimum. Chlorine is applied to the filter influent 1 night every 10 days, 1 night a week, or possibly 1 to 2 successive nights a week. The frequency of the treatment is determined by experience at each particular plant.

The amount of chlorine required for fly control is less than that used for the relief of ponded filters. The application should be sufficient to give a slight chlorine residual at the spray nozzle; 3 to 10 ppm. of chlorine will usually be required.

At Perkasie, Pa., a 0.5 mgd. plant, chlorine is applied to the filter influent from 6:00 p.m. to 6:00 a.m. 2 to 3 successive nights every other week. Chlorine requirements seldom exceed 15 lb. per night, and the results are very effective.

Filter Improvement

When chlorine has been used for trickling filter fly and odor control, the personnel at the plants have invariably noted, and in some cases reported, how chlorination kept the filters cleaner than they had ever been before; how the pipe lines were cleaned of growths; how the spray nozzles were much cleaner than before; how, for the first time algae growths were kept off the filters; and how much the appearance of the filters was improved.

Chlorination for trickling filter odor control and for psychoda fly control is good operation practice. In some cases, the quality of the trickling filter effluent is maintained at a higher level than before. At more than one plant, from the standpoint of operation, the sloughing of material from the filter has been even of

more importance than odor control, the original intention of the chlorination.

Activated Sludge—Sludge Bulking Control

In 1926, De Laporte, of the Ontario Provincial Health Department, applied a solution of bleaching powder to return sludge to correct disturbances at activated sludge plants giving inferior effluents. At the Barnsley, England activated sludge plant, Bell [19] in 1929 reported plant improvement by applying bleaching powder to the raw sewage prior to sedimentation. He derived even greater benefits by a secondary application of chlorine to the return sludge at the point of mixture of the return sludge with the settled sewage. Gascoigne [6], in speaking of this plant, states that after this treatment was put into practice the Barnsley plant took care of the load for the first time without bypassing the secondary units, and the quality of the effluent was improved.

In 1934, Smith at Lima, Ohio [30,31], at the suggestion of Purdy, tried chlorination of the return sludge during a period of bulking and found that small amounts of chlorine effectively reduced fungus growths and stopped the bulking. As early as this it was found that the amount of chlorine required was governed by the percentage of solids in the return sludge. In November, 1935, Lancaster, Pa. successfully added chlorine to the return sludge to remedy a sludge bulking condition. Other plants soon followed in rapid succession. The Radnor-Haverford, Pa., activated sludge plant was among the early users of chlorine for this purpose.

The role of chlorine in activated sludge bulking control has been variously explained. Chlorination undoubtedly kills part of the biological life in the return sludge. Tapleshay best expresses it by stating that he believes the chlorine restores the balanced load between the organic matter and the biological life present in the sludge.

The best procedure for sludge bulking control is that outlined by Tapleshay [32, 33] after visiting 50 activated sludge plants in the United States. Briefly, the procedure is to apply chlorine to the return sludge at least two minutes ahead of where it mixes with the primary effluent; to use chlorine in an amount computed from the Tapleshay formula; to keep the rate of return sludge as near a constant percentage of the flow as possible during chlorination; and to seldom adjust the chlorine dosage day by day. The reason for the latter is that as the sludge index decreases the concentration of the return sludge increases as it becomes more compact. Chlorination is continued until the sludge index returns to the normal value for that particular plant.

In applying chlorine to the return sludge, the effluent usually gets turbid in the first 12 hours as the reaction sets in. This fact has caused some who have tried chlorination to discontinue the treatment and call it a failure. If chlorination had been continued, they would have found that the turbidity gradually decreased, along with the sludge index. Usually a decided improvement is noted in 3 or 4 days. Chlorination for sludge bulking is usually discontinued in 7 to 10 days.

The amount of chlorine required to control sludge bulking increases with the suspended solids concentration and with the sludge index. Tapleshay's chart [33] covers a wide range of values for these two figures which make use of anywhere from 2 to 24 lb. of chlorine per 100,000 gal. of returned sludge. Normally, the amount of chlorine required will vary between 2 and 8 ppm., with an average of 5 ppm., based on the return sludge flow.

Activated Sludge—Diffuser Plate Cleaning

The clogging of air diffuser plates in aeration tanks at activated sludge plants has, at some plants, become a major problem. Roe [34] in a paper published in 1934 described the causes of clogging and summarized the various practices used for cleaning the plates. Chlorine treatment is mentioned among the various procedures. Franklin [35] and Jackson [36] have reported on the use of chlorine, given details of the method, and have concluded that the use of chlorine is an effective and economical method of cleaning the plates.

Chlorine is added directly into the air header, one unit at a time. The usual practice is to use intermittent applications of chlorine, about 3 or 4 lb. per hour for about 2 to 3 hours during the day. Continuous treatment will require about 12 to 15 lb. of chlorine.

The use of chlorine for cleaning diffuser plates does not give continuous relief but, if used properly, it should not be necessary to remove the plates for cleaning more often than every 2 years or so. Cleaning the plates with acid or by burning is a considerable undertaking and, if the intervals between such a procedure can be lengthened, an occasional application of chlorine is definitely worthwhile.

Hatfield [37] of Decatur warns that the addition of chlorine to the air header may not at first appear to be of any value. He found that the action is somewhat delayed in its effect but that it works and has the advantage of being able to keep aeration tanks in operation while the plates are being treated.

Chlorine as Adjunct to Sludge Disposal

Foaming Control

Foaming is a problem at many sewage plants. Schlenz [38] mentions 8 possible causes of foaming, discusses each, and then gives 10 remedies. Many of these remedies consume a considerable amount of labor and are costly to execute. The use of chemicals such as lime or chlorine are the two chemical methods listed. Foaming often occurs when the pH of the digester contents is above 7.0. Lime is most generally tried first but when this fails chlorine has often been found to be the answer to the problem. It has been particularly applicable where foaming has been rampant at Imhoff tanks.

In 1926, Enslow, at Austin, Texas [18], applied chlorine to the incoming crude sewage entering one of the Imhoff tanks. Even small amounts of chlorine reduced the tendency to foam and produced a more satisfactory tank effluent. Similar results have been reported at Lufkin, Texas [18] in 1928, and shortly thereafter at Breckenridge, Texas. Samson [39], in 1937, reported that for over 2 years prechlorination had been successful in controlling foaming at the Tonawanda, N.Y., plant.

Industrial wastes in the sewage often cause Imhoff tanks to foam. One of the earliest to report the use of prechlorination ahead of Imhoff tanks receiving sewage containing industrial waste was West [40], at Stockton, California. The wastes were those from canneries and a cheese factory. Foaming occurred practically the year round but was always accentuated during the canning season. Prechlorination greatly reduced the foaming and the effluent because decidedly clearer.

Blohm [41], at the Westminster, Md., plant, had an unusual experience with distillery wastes. In 1936, a year after the plant was placed in operation, the digester foamed. Lime with recirculation failed to stop foaming even when the pH of the digester contents was 7.2. The addition of 16 lb. of chlorine in the form of calcium hypochlorite stopped the foaming completely.

Chlorine for foaming control of Imhoff tanks is always added as prechlorination ahead of the tank. An application of 3 to 15 ppm. of chlorine usually suffices to greatly reduce the foaming and, in some instances, completely stop it.

Supernatant and Waste Activated Sludge Chlorination

The return of the supernatant liquor from the digester has often been a problem at many sewage plants, particularly when its return to the primary tank influent has resulted in an upset plant due to the overload created. At times, even secondary treatment units have been affected. Chlorination has often been the answer to the problem and it is expected to have widespread use in the future.

It is almost impossible to chlorinate the supernatant to a chlorine residual for it generally has a chlorine demand of 300 to 400 ppm. An application of 20 to 80 ppm. of chlorine per million gallons of supernatant usually suffices to take the load off the plant. The supernatant can be returned in the early morning when the chlorine demand of the raw sewage is at a minimum. The supernatant-raw sewage mixture is then chlorinated as it enters the primary settling basin. The supernatant can also be fed slowly but continuously throughout the day and in that way the prechlorination dose need be increased only slightly above normal.

The return of excess activated sludge to the primary settling tank at activated sludge plants is often a source of trouble. The activated sludge becomes septic and rises to the surface, retarding the normal settling and, hence, interfering with the activated sludge process. At the Willow Run bomber plant, Detroit, Michigan, Herda [42,43] was confronted with an overloaded plant due to both the return of the digester supernatant liquor and waste activated sludge to the primary settling basins. He reported that chlorination of the waste activated sludge and the supernatant with 2 to 8 ppm. of chlorine, based on the waste activated sludge flow, resulted in great improvement in the settling in the primary tanks and in the appearance of the plant effluent.

Sludge Thickening

The problem involved in returning the waste activated sludge to the primary units is quite often avoided by sending it to the digesters, or by drying it on vacuum filters. In either event, the excess return sludge first must be concentrated in tanks.

About 1930, Goudey and Bennett [44] eliminated the ill effects of returning waste activated sludge to the raw sewage by concentrating the sludge in separate tanks and then pumping it to the digesters. They applied chlorine to the upper strata

of the liquid at the rate of about 25 lb. of chlorine per million gallons of sewage passing through the plant. In this way, they were able to avoid bulking and reduce the water content to 95 per cent.

Phoenix, Ariz., Topeka, Kans., Rockville Center, N.Y., and, more recently, the Tallman's Island plant of New York City have used chlorine for this purpose. It is usually used in the summer when the return sludge deteriorates most rapidly.

For satisfactory thickening, a chlorine residual must be maintained in the clear liquor above the settling or the compacting sludge in the tank. Addition of chlorine to the sludge as it enters the tank seems to give the best chlorine residual control. All who have tried this treatment agree that a 1 ppm. chlorine residual must be maintained in the clear liquid above the sludge.

Summary

Chlorine has many other minor uses in sewage treatment works operation which are not discussed in this paper. Regardless of the purpose for which chlorine is used—whether it be for effluent disinfection or as an aid to primary treatment, secondary treatment, or sludge disposal—the best advice concerning its use is to chlorinate intelligently, but not blindly.

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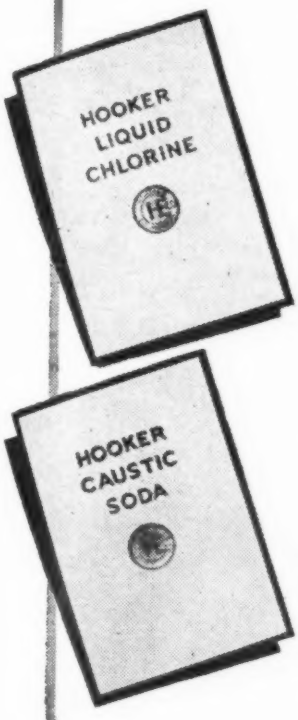

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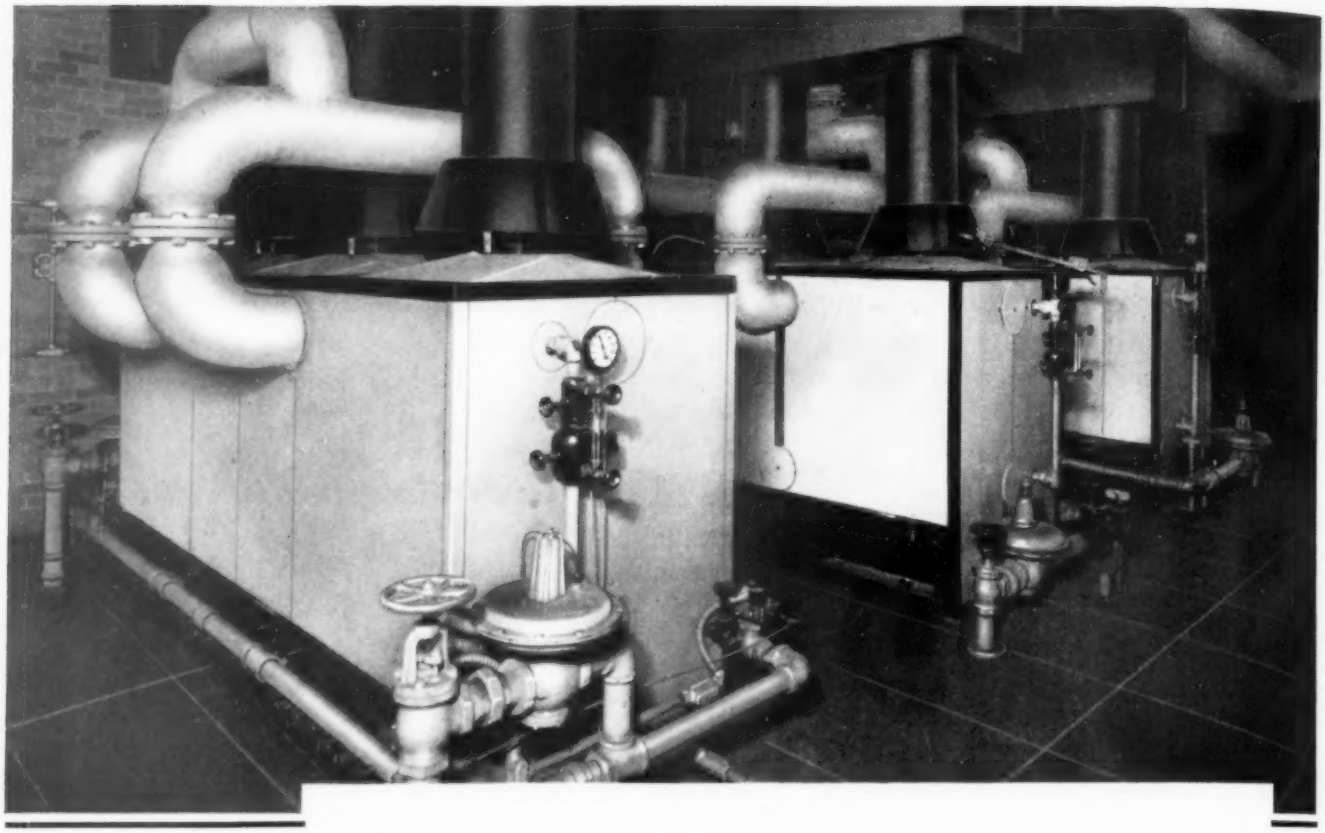

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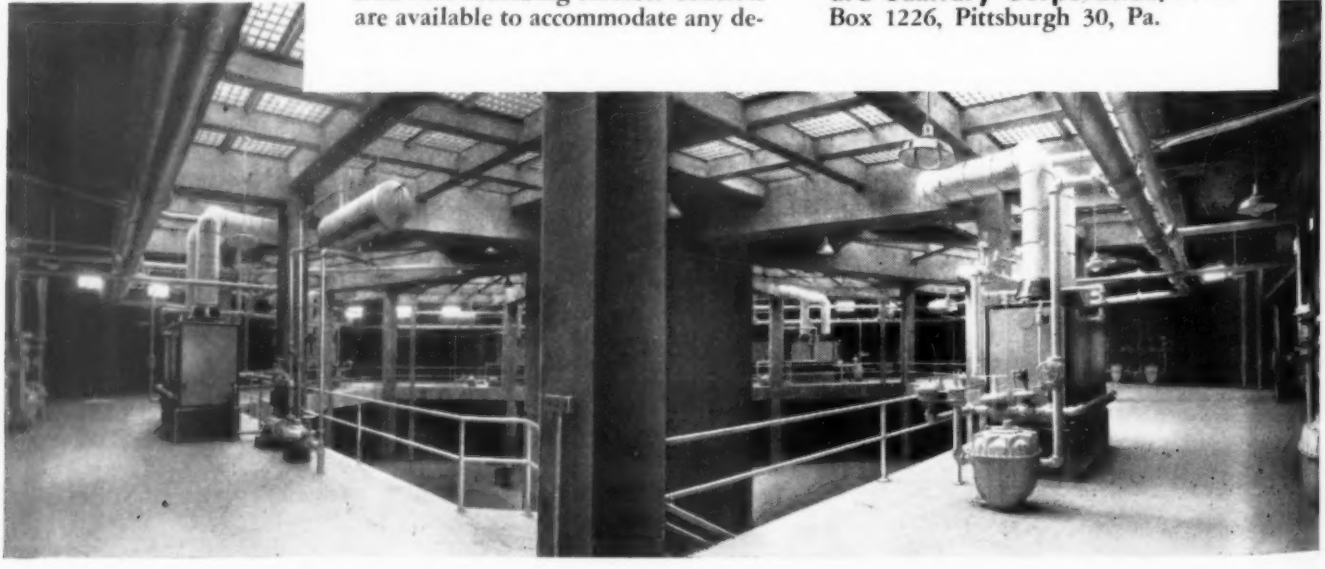

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	1-GA-4E	31,500		210	39,350	56	40½"	16"	19¼"
	1-GA-5E	42,000		280	52,500	75	40½	16	22¼
	1-GA-6E	52,500		350	65,600	94	40½		25¼
	2-GA-4E	63,000		420	78,750	113	50½	16	19¼
	2-GA-5E	84,000		560	105,000	150	50½	16	22¼
	2-GA-6E	105,000		700	131,200	188	50½	16	25¼
	2-GA-7E	126,900		840	157,500	225	50½	16	28¼
	4-GA-8E	147,000		980	183,750	263	54	16	37¼
	4-GA-9E	168,000		1,120	210,000	300	54½	16	40¼
	4-GA-11E	210,000		1,400	262,500	375	54½	16	46¼
	4-GA-13E	252,000		1,680	315,000	450	56	16	52¼
0-GS-4E		61,200		980	76,600	109	52¼	16	33¾
0-GS-5E		81,600	255	1,240	102,000	146	53	16	37¾
0-GS-6E		102,000	340	1,500	127,500	182	52½	16	41¾
1-GS-4	1-GW-4	146,000	425	1,770	182,500	261	54½	19	25
1-GS-5	1-GW-5	186,000		2,030	232,500	332	56¾	23	25
1-GS-6	1-GW-6	225,000	610	2,300	281,500	402	56½	27	25
1-GS-7	1-GW-7	265,000	775	2,560	331,000	473	57	31	25
1-GS-8	1-GW-8	305,000	940	2,820	381,000	545	59¼	35	25
1-GS-9	1-GW-9	344,000	1,105		431,000	616	58½	39	25
1-GS-10	1-GW-10	384,000	1,270		480,000	686	59¼	43	25
1-GS-11	1-GW-11	424,000	1,435		530,000	757	59	47	25
4-GS-6	4-GW-6	480,000	1,600		600,000	857	74	27	41½
4-GS-7	4-GW-7	576,000	1,765		722,000	1030	75	31	41½
4-GS-8	4-GW-8	672,000	2,000	3,200	840,000	1200	77	35	41½
4-GS-9	4-GW-9	768,000	2,400	3,840	960,000	1372	77¾	39	41½
4-GS-10	4-GW-10	864,000	2,800	4,480	1,079,000	1543	79½	43	41½
4-GS-11	4-GW-11	960,000	3,200	5,120	1,200,000	1715	80	47	41½
4-GS-13	4-GW-13	1,152,000	3,600	5,760	1,440,000	2060	75	61¼	41½
4-GS-15	4-GW-15	1,344,000	4,000	6,400	1,680,000	2400	77	69¼	41½
4-GS-17	4-GW-17	1,536,000	4,800	7,680	1,920,000	2740	77¾	77¼	41½
4-GS-19	4-GW-19	1,728,000	5,600	8,960	2,162,000	3090	79½	85¼	41½
4-GS-21	4-GW-21	1,920,000	6,400	10,240	2,400,000	3425	80	93¼	41½
4-GS-22	4-GW-22	2,016,000	7,200	11,520	2,520,000	3600	77	103½	41½
4-GS-25	4-GW-25	2,304,000	8,000	12,800	2,880,000	4120	77¾	115½	41½
4-GS-28	4-GW-28	2,592,000	8,400	13,440	3,240,000	4625	79½	127½	41½
4-GS-31	4-GW-31	2,880,000	9,600	15,360	3,600,000	5145	80	139½	41½
4-GS-33	4-GW-33	3,072,000	10,800	17,280	3,840,000	5480	77¾	153¾	41½
4-GS-37	4-GW-37	3,456,000	12,000	19,200	4,320,000	6165	79½	169¾	41½
4-GS-41	4-GW-41	3,840,000	12,800	20,480	4,800,000	6850	80	185¾	41½
			14,400	23,040					
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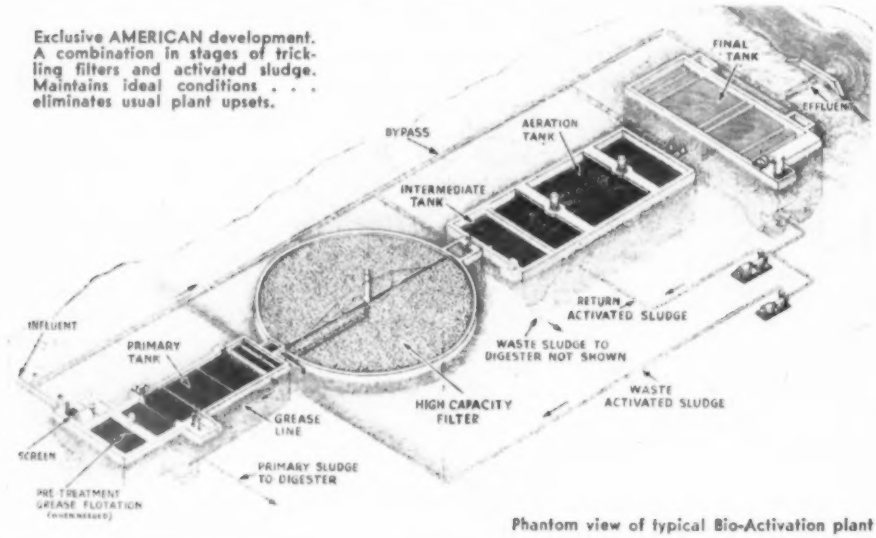

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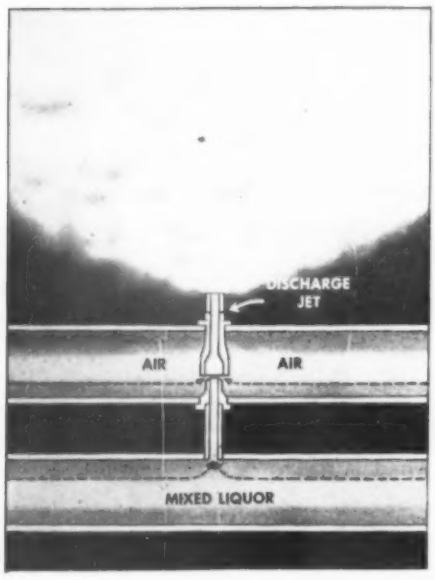

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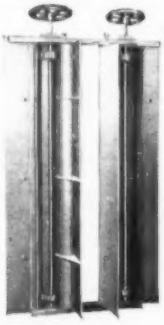

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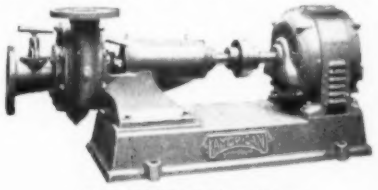

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EXPERIENCE IN THE OPERATION OF STANDARD TRICKLING FILTERS*

By DOUGLAS E. DREIER
Walker Process Equipment Co.

THIS article reviews practices in the operation of trickling filters of so-called "standard rate" design. It is largely based upon data and comments obtained from 35 superintendents, engineers, chemists and operators of 31 representative plants, through detailed questionnaires and by supplementary correspondence. The interest and complete cooperation of the following contributors are gratefully acknowledged:

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The data tabulated in Tables I and II indicate a wide variation in design, capacity and loading at the plants forming the basis for this summary. It will be observed that eighteen of the plants receive industrial wastes of consequence, some discussion of which will be included later.

Filter Loading

It is not the purpose of this discussion to enter the somewhat controversial subject of filter loading; however, a study of the data contributed reveals several plants operating, apparently with reasonably good results, at average loadings considerably in excess of commonly accepted design standards.

The summary of operation data from Fort Dodge, Iowa (Table III), is of interest as it relates to the operation of a two-stage standard trickling filter plant under heavy loading of packinghouse wastes. The sewage is first passed through a preaeration tank 18 feet x 15 feet x 7.5 feet liquid depth. Air is applied continuously at 300 cfm. through a series of perforated pipes located near the tank bottom. (The grease floated is skimmed off and sold.) The flow is then subjected to 1.65 hr. of primary sedimentation followed by secondary treatment on two-stage trickling filters, each stage consisting of two 151-ft. diameter filters, 8 ft. deep, equipped with reaction rotary distributors. An intermediate settling tank is included in the design. The filter underdrains consist of slotted 6-in. tile, laid with open joints, radiating from the center of the filter to the periphery. The underdrain tile connect with ventilating stacks of the same diameter at 18-in. centers around the filter periphery.

The data in Table III are most interesting in demonstrating the ability of these trickling filters to perform under heavy overload. An average of 7.9 ppm. nitrates was contained in the effluent in spite of the heavy organic loading. The maximum monthly average B.O.D. reduction was 93.4 per cent, and the minimum was 78.9 per cent during the fiscal year reported. The maximum monthly average B.O.D. reduction occurred during July, the month which had the highest B.O.D. loading. That operation of the Fort Dodge plant under such a heavy loading was not without its difficulties will be observed in the latter discussion of operation problems.

Operation results at Decatur, Illinois, as reported by Hatfield for the month of August, 1944, and tabulated in Table IV, are also of interest. During that month the activated sludge portion of the plant was not operating, and although the trickling filters were loaded at 830 lbs. B.O.D. per acre-ft. per day, an average overall reduction of 87.3 per cent was obtained. The average B.O.D. removal by the filters and final clarifiers was 80.6 per cent. The Decatur trickling filters are of the fixed-nozzle design, 3 acres in area and 6 ft. deep. The

TABLE I.
General Information Regarding Contributing Plants

Plant	Connected Population	Type Sewers (1)	Average Flow (mgd.)	Avg. Prim. Sed. Period (hr.)	Type Prim. Tr. (2)	Avg. Final Sed. Period (hr.)	Type Final Tank (3)	Avg. 5-Day B.O.D. (ppm.) Raw Sewage	Prim. Eff.	Filter Eff.	Final Eff.	Rel. Stab. Eff. (days)	Industrial Wastes Tributary
Akron, Ohio	275,500	S & C	47.90	1.6	I	1.25	P	269	207	67	46	3	Synthetic rubber
Albermarle, N. C.	9,000	S	1.25	3.07	D	2.07	M	300	130	40	15	10	Textile dye
Aurora, Ill.	51,000	C	7.77	1.15	D	1.11	M	117	72	22	14	13	—
Bemidji, Minn.	6,000	S	0.45	1.5	D	1.5	M	—	—	—	—	—	—
Bloomington-Normal, Ill.	40,000	C	4.20	—	I	—	M	160	70	—	12	10	—
Bowling Green, Ohio	5,000	C	1.00	2.0	D	—	P	275	176	—	38	—	Tomato cannery
Clinton, Ill.	7,000	C	0.75	—	I	—	P	—	—	—	—	10	—
Corpus Christi, Texas	100,000	S	10.0	1.5	D	1.5	M	200	120	25	20	—	Seasonal cannery, milk
Dayton, Ohio	325,000	S	34.4	1.7	I	1.6	M	227	137	46	33	—	Milk, packinghouse, paper
Decatur, Ill.	60,000	C	11.0	1.0	I & D	0.6	M	198	129	32	25	5	Corn products (6)
Des Moines, Iowa	160,000	C	15.3	3.5	D	2.75	M	200	—	—	41	5–12	Packinghouse
Plainfield, N. J.	60,000	S	4.25	1.0	D	1.0	M	629	320	26	13	10	—
Durham, N.C.	20,000	S	1.77	3.5	D	2.5	M	375	264	—	68	—	Textile dye
Elgin, Ill.	34,000	C	4.57	3.4	I & D	0.5	M	128	94	46	41	—	—
Fargo, N.D.	34,000	C	1.94	2.9	D	—	None	213	167	45	—	6	Gas plant, milk
Fort Dodge, Iowa	23,000	S	2.42	1.65	D	1.48	M	751	547	145(5)	105	—	Packinghouse (7)
Galesburg, Ill.	26,000	C	4.46	2.7	D	1.2	M	184	112	56	44	—	—
Griffin, Ga.	13,000	S	0.80	0.67	D	—	P	200	—	—	10	—	Laundry, textile
Huntington Beach, Calif.	3,000	S	0.30	2.0	D	—	None	—	—	—	—	—	—
Lebanon, Pa.	24,000	S	3.61	0.5	I	1.5	M	—	—	—	—	5	—
Litchfield, Ill.	6,000	C	0.52	3.0	D	3.0	M	360	220	16	5	10	Milk, oil
Madison, Wis.	35,000	S	4.82	2.25	I & D	3.44	M	248	139	50	33	13	Packinghouse
McPherson, Kan.	7,000	S	0.75	1.5	D	1.25	P	—	—	—	—	—	—
Oconomowoc, Wis.	4,600	S	1.13	2.4	D	2.1	M	140	99	15	8	10	Milk, pea cannery
Plymouth, Wis.	4,270	S	0.46	2.6	D	2.6	M	—	—	—	—	—	Milk, general cannery
Pontiac, Ill.	9,600	C	0.80	1.5	D	—	M	—	—	—	—	10	Milk
Pontiac, Mich.	70,000	S & C	7.70(4)	1.0	I	1.0	M	253	138	52	38	5	Cutting oil, grease
San Bernardino, Calif.	65,000	S	5.50	3.75	D	3.75	M	170	60	11	6	—	Chromic acid
Van Wert, Ohio	9,000	C	0.96	1.0	D	1.5	M	305	242	18	15	—	Cannery, milk, plating
Waynesboro, Pa.	8,500	S	0.88	—	D	—	M	236	—	—	31	10	—

(1) S—separate; C—combined.
(2) I—Imhoff tank; D—separate sludge digestion.
(3) P—plain hopper-bottom; M—mechanical.
(4) Part of flow treated by activated sludge.
(5) Effluent of second stage filters.
(6) Population equivalent 60,000-100,000.
(7) Population equivalent about 66,000.

high loading is largely due to starch wastes from a corn products plant.

Operation results at Akron, Ohio, for the year 1944, as reported by Schaetzle, are summarized in Table V. The Akron plant, containing 14 acres of fixed-nozzle filters 10 ft. deep, has been overloaded hydraulically and by solids for many years.

Loading data from many other plants could be added to the above as supporting evidence of the ability of standard trickling filters to provide treatment at higher loadings than they are commonly designed to accommodate. The use of slightly larger filter media to reduce ponding tendencies, adequate filter ventilation design, and the provision of recirculation facilities to assure continuous filter operation should permit considerably more optimistic design than has been practiced in the majority of designs. Provision of facilities for 1:1 recirculation at average flow can prove most helpful to the operator at times, and evidence of the general appreciation of this fact is found in the increased number of new designs including provision for recirculation. Loadings of 500 to 800 lb. B.O.D. per acre-foot do not appear unreasonably high, provided a fresh sewage is applied to the filters, with lower loadings reserved for situations where outlet conditions are critical or where local factors preclude projection of population equivalent loadings with sufficient assurance to warrant any optimism in design.

Filter Media

Table II includes information regarding the filter media at the various plants. It will be observed that experience with filter media has been generally satisfactory at the plants contributing to this summary, although some disintegration of media is reported.

Hatfield (Decatur, Ill.) reports that after 20 years service the filter stone has disintegrated from 1½ in. to about ¾ in., which has been partially responsible for ponding difficulties.

Johnson (Elgin, Ill.) reports that limestone media 1 to 2 in. in size placed in the Elgin filters in 1927 disintegrated sufficiently by 1939 to cause serious surface ponding. In 1941 the filter media at Elgin was removed and screened, and media retained on a 1½-in. screen was re-used. Twenty in. of 1½ to 3-in. limestone was added, followed by a 14-in. top layer of 2¼ to 3½-in. granite, both of which passed the 20-cycle sodium sulfate soundness test. No distintegration of media has occurred at Elgin since 1941.

Magennis (Fort Dodge, Iowa) reports that limestone media which passed the 20-cycle sodium sulfate soundness test has not successfully withstood weathering. It has fractured badly with some of the pieces being quite small. Granite media in the other two Fort Dodge filters is still in good condition. Magennis calls attention to an important matter in the placing of filter media, suggesting that filter ponding has been most severe in the areas where media was dumped on the beds directly from the trucks, resulting in pockets of fine material. This again emphasizes the importance of care in the placing of filter media.

Care in selecting, grading and placing filter media is one of the most important factors affecting the operation of trickling filters. Unfortunate experiences have come from inadequate attention to this important item. It is thought highly advisable to specify that only a small percentage, never greater than 5 per cent, of a filter media can be smaller than the lower specified size. Fine material fills the voids in the larger media and, when much fine material is present, it is apt to segregate and form pockets during placing. It is important to re-handle media before placing it in the filter in order to avoid excessive quantities of fines and also to avoid segregation. Media should be re-handled with forks and placed with wheelbarrows or conveyors.

In general, experience with filter media sufficiently durable to withstand the 20-cycle sodium sulfate soundness test, in accordance with the sampling and laboratory procedures set forth in the A.S.C.E. *Manual of Engineering Practice No. 13*, has been satisfactory. Due to probable variation in quality of stone on various ledges of a quarry, and even at various places on the same ledge, it is important to exercise care that media is obtained from the same ledge area from which the soundness test sample is obtained. Reliance should not be placed in the results of an ancient soundness test submitted as evidence of general acceptability of the stone from a given quarry for use in trickling filters.

TABLE III.
Summary of Operation Data at Fort Dodge, Iowa, April 1, 1943 to March 31, 1944

	Avg.	Max.	Min.
Raw sewage flow, mgd	2.42	4.92	1.28
Filter loading:			
Flow, mgad. to each stage	3.02	6.15	1.60
Lb. B.O.D. per acre-ft. per day:			
First stage filters	1,741	3,078	615
Second stage filters	964		
B.O.D. data, ppm.:			
Raw sewage	751	1,327	264
Primary effluent	547	767	265
Average per cent removal	26.4		
First stage filter effluent	359	687	168
Intermediate clarifier effluent	304	559	115
Avg. per cent removal primary effluent to intermediate clarifier effluent	44.5		
Second stage filter effluent	145	394	34
Final effluent	105	288	25
Avg. per cent removal intermed. clarifier effluent to final effluent	67.6		
Avg. per cent removal by both stages filters and clarifiers	82.1		
Avg. overall B.O.D. reduction	86.6		
Nitrites in final effluent, ppm	0.8	4.25	0.10
Nitrates in final effluent, ppm	7.9	15.5	0.85
Outlet stream flow, cfs	1,400	5,300	25

TABLE II.
Trickling Filter Data

Plant	No. & Diam. (ft.) or Area (acres)	Depth (ft.)	Type of Dosage	Type of Distrib. (1)	Filter Media					Filter Loading			Effluent Nitrates	
					Type	Size (in.)	Weathering	Years in Service	Soundness Test Used (2)	Lb. B.O.D. per Acre-Ft. Av.	Lb. B.O.D. per Acre-Ft. Max.	Av. Cu. Ft. Media per Lb. B.O.D.	Avg.	Min.
Akron, Ohio	14 ac.	10	Siph.	N	Limestone	1 –2½	Mod.	17	A	590	703	74	1.32	0.16
Albemarle, N.C.	1-97	8	Cont.	R	Granite	1½–3	Mod.	7	None	—	—	—	—	—
Aurora, Ill.	3.74 ac.	6	Siph.	N	Limestone	1½–2	Sl.	16	B	192	867	227	6.35	2.8
Bemidji, Minn.	1-100	6	Siph.	R	Field Stone	2½–4	—	10	—	—	—	—	—	—
Bloomington-Normal, Ill.	2.5 ac.	8	Siph.	N	Limestone	2	Sl.	18	—	188	313	232	—	—
Bowling Green, Ohio	4-100	7.5	Pumps	M	(3)	—	Mod.	10	A	—	—	—	—	—
Clinton, Ill.	1-140	7.5	Siph.	R	Limestone	1 –4¼	Sl.	10	A	—	—	—	—	—
Corpus Christi, Texas	4-160	6.5	Grav.	R	Limestone	1¾–3	Sl.	8	None	—	—	—	—	—
Dayton, Ohio	20-165	7.5	Siph.	R	Slag	1½	Sl.	6	None	515	772	85	4.6	1.14
Decatur, Ill.	3.0 ac.	6	Siph.	N	Stone	1½	Bad	20	None	830	1,640	53	—	—
Des Moines, Iowa	12-152	7	Siph.	R	Gravel; stone	1½–3	Sl.	5	A	324	—	135	—	—
Plainfield, N.J.	1.78 ac.	6	Siph.	N	Trap rock	1½–2	None	29	—	1,080	—	40	—	—
Durham, N.C.	0.92 ac.	7	Siph.	N	Stone	1	None	17	None	556	—	78	—	—
Elgin, Ill.	1.54 ac.	8	Siph.	N	(4)	1¼–3	(7)	3(7)	A	264	330	165	6.7	2.0
Fargo, N.D.	1.66 ac.	8	Siph.	N	Red granite	2 –2½	None	10	None	203	261	215	—	—
Fort Dodge, Iowa	4-151	8	Siph.	R	(5)	1½–2½	(8)	7	A	1,741(9)	3,078(9)	25	7.9	0.9
Galesburg, Ill.	1.06 ac.	6	Siph.	N	Limestone	1 –1½	Mod.	14	C	488	804	76	—	—
Griffin, Ga.	1-75; 1-105	6	Siph.	R	Stone	2½	—	8	—	—	—	—	—	—
Huntington Beach, Calif.	1-155	6	Siph.	N	Stone	1½–2½	Sl.	9	—	—	—	—	—	—
Lebanon, Pa.	1.3 ac.	6	Siph.	N	(6)	1½–3	(8)	17–32	None	600	1,475	73	—	—
Litchfield, Ill.	1-140	6	Pumps	M	Limestone	2½–4	Mod.	8	—	—	—	—	—	—
Madison, Wis.	2.0 ac.	10	Siph.	N	Dolomite	1 –1½	Sl.	17	—	279	434	174	7.0	3.2
McPherson, Kan.	1-90	8	Siph.	R	Stone	2	None	14	A	—	—	—	—	—
Oconomowoc, Wis.	2-140	7	Pumps	M	Gravel	2½–3	Sl.	8	—	—	—	—	—	—
Plymouth, Wis.	1-140	7	Pumps	R	—	—	—	—	—	—	—	—	—	—
Pontiac, Ill.	1-120	7	Pumps	M	Limestone	1½–2½	Sl.	9	—	—	—	—	—	—
Pontiac, Mich.	8-110	6	Siph.	R & M	—	1½–3	Mod.	25	—	136	—	320	—	—
San Bernardino, Calif.	2.46 ac.	7	Siph.	N	Gravel	1½–2½	None	17	—	175	—	250	—	—
Van Wert, Ohio	2-110	8	Siph.	R	Limestone	1 –2	None	10	A	—	—	—	—	—
Waynesboro, Pa.	1-145	6	Siph.	R	Limestone	1½–2½	Sl.	10	—	759	1,620	58	—	—

(1) N—fixed nozzles; R—reaction rotary dist.; M—motor-driven rotary dist.
(2) A—20-cycle Na_2SO_4; B—50-cycle freezing and thawing; C—Brard's test.
(3) Slag used for top 18 in., remainder limestone.
(4) Granite used for top 14 in., remainder limestone.
(5) Two filters limestone; two filters granite.
(6) Two filters limestone; one filter trap rock.
(7) Filter media replaced in 1941. No weathering since.
(8) Limestone weathering bad.
(9) First stage filters.

Operation Problems

The questionnaires which were distributed to form a basis for this summary were most complete, and direct quotation will be used frequently in discussing the various trickling filter operation problems.

Ponding

A major problem in trickling filter operation has been that of ponding with resulting decrease in operating efficiency and frequently an increase in odor problems. About one-half of the operators contributing to this summary report ponding difficulties to varying degree.

Schaetzle reports that the Akron plant has been overloaded hydraulically and by solids for many years, which results in a ponding problem. He states:

"The plant was designed for 33 mgd. and 185 ppm. suspended solids in the raw sewage. The Imhoff tank effluent in 1944 contained 167 ppm. suspended solids with a flow of 47.9 mgd. The filters are protected by a 20-mesh vertical traveling screen, cleaned by water spray. Ponding is due to the overload. Filters pond in spots aggregating probably 10 per cent of the total area and in the top 6 to 8 in. We loosen the surface with a pick at ponding spots 2 to 3 times annually. Once every other year we harrow the entire 14 acres with a peg-tooth horse drawn harrow."

Allison (Corpus Christi, Texas) reports some ponding at the surface during the summer months due apparently to algal growth. Dragging a hooked bar over the surface is usually a sufficient remedy.

Mackin (Madison, Wis.) reports ponding at or slightly below the surface, apparently due to algal and other growths and accumulated solids joining together as a thin mat. This ponding occurs 2 or 3 times annually, affecting an area of 25 to 33 per cent of the filters. Mackin reports the use of chlorination in the summer for ponding control. The filters are cultivated in spring and fall with a horse drawn 2-wheeled farm cultivator, equipped with eight shovels, to a depth of about 8 in. A horse drawn peg-tooth harrow is then used to level the surface. Downes (Plainfield, N.J.) indicates that when small patches of ponded area occur, the surface of the filters is harrowed with a spike-tooth harrow and tractor. This is done about once annually.

TABLE V.
Summary of Operation Data for Akron, Ohio, 1944

	Avg.	Max.	Min.
Raw sewage flow, mgd	47.9	94.0	27.2
Filter loading, mgad.	3.5		
Lb. B.O.D. per acre-ft. per day	590	703	482
B.O.D. date, ppm.*:			
Raw sewage	269	310	222
Primary effluent	207	241	187
Filter effluent	67	93	41
Final effluent	46	75	27
Per cent reduction, primary effluent to final effluent	77.8	68.9**	85.6**
Per cent overall B.O.D. reduction	82.9	75.8**	87.8**
Nitrates in final effluent, ppm.*	1.32	2.56	0.16
Outlet stream flow, cfs. (1931–35)	273		25

*Maximum and minimum data are monthly averages.
**Correspond to B.O.D. data above.

corrected by going over the ponded areas with picks. Working the ponded areas of the twenty 165-ft. diameter filters at Dayton requires 160 man-hours of labor.

Magennis (Fort Dodge, Iowa) reports ponding of the first stage filters to a serious degree, and to a lesser extent on the second stage filters at least twice a year. He continues:

"The first stage filters pond over about half their areas and the second stage filters over about a fourth of their areas. The clogging seems to extend the entire 8 ft. of their depths, especially on the areas where the rock was hauled out on the beds and dumped directly from the trucks. This deposited any fines, which may have been in the rock, all in one spot on each of the filter beds.

"For the last five years the average overload on the plant has been 78 per cent with an overload of 96 per cent last year. The maximum overload last year, figured on a monthly average, was 154 per cent. About 74 per cent of the total overload comes from a meat packing plant.

"In the spring and fall, when the ponding is worse, the beds are flushed with a fire hose carrying about 105 lb. pressure. This relieves the condition better than anything we have tried.

"Chlorine is used for odor control. It has been used in the past in an effort to relieve ponding, but to no avail even at dosages of 1,000 lb. per 24 hr. per filter for continuous periods of one week duration. The chlorine was applied to the filter influents."

The following is extracted from the 1943-44 annual report on the Fort Dodge plant:

"A clam shell was hired on November 27 to remove some rock from No. 1 filter down

"Samples of this sludge were carefully taken at 1-, 4- and 8-ft. (levels) and analyzed for grease, chloroform soluble on a dry basis, and organic material. That from the 1-ft. level showed 18.7 per cent grease and 63.8 per cent organic. That from the 4-ft. level showed 10.7 per cent grease and 67.6 per cent organic, while that from the 8-ft. level, or the floor of the filter, gave 22.3 per cent grease and 76.1 per cent organic. It seemed a little peculiar that the highest percentages should be found at the bottom of the filter but this may have been caused by the thorough flushings given a few months previous. It is evident that flushing with a fire hose and spotting of the distributor arms (stopping the distributors every foot or so and allowing them to remain stationary for thirty min. or more) will not correct this continuous problem of ponding, but only serves as a slight relief. It was found the following month that chlorine, applied at heavy dosages, would not correct this condition either. As long as the peak flows, B.O.D., and solids loadings remain high and the plant is not expanded or altered to meet these conditions it seems very unlikely that results of operation will improve very much."

Rehabilitation of the filters at Elgin, Ill., in 1941 eliminated surface ponding, however, Johnson reports that clogging of the beds at a depth of 8 to 16 in. has been in evidence during the late winter months of the past three years. Johnson states:

"It is my opinion that during cold weather, bacterial life in the top portion of the beds is retarded and insufficient to act properly upon the suspended solids which are retained, thereby causing an excessive film development which is responsible for the clogging. It appears to me that rotary distributors in place of the fixed-nozzle type of distribution would afford more uniform and continuous application which would be beneficial in maintaining the desired higher temperatures to induce bacterial action in the top portion of the beds.

"During the past winter chlorine was applied to the filters for one 10-hour night period at 3-week intervals in an effort to induce artificial sloughing. The chlorine dosage was sufficient to maintain 3.2 to 5 ppm. residual at the nozzles. Increased solids unloading occurred after each application of chlorine, and nitrate nitrogen analyses of filter effluent indicated the beds apparently were not clogged to the extent of previous years; however, the spring unloading was as heavy and enduring as in 1943 and 1944. The unloading extends from April to June, and the filters do not recover to function properly until July. Low overall treatment plant efficiencies reflect to this extensive sloughing period and inadequate final sedimentation capacity as now provided."

Hunt (Galesburg, Ill., Sanitary District) states:

"Ponding occurs during the late winter and early spring. The area covered by

TABLE IV.
Summary of Operation Data for Decatur, Ill., Sanitary District, August, 1944

	Avg.	Max.	Min.
Raw sewage flow, mgd	13.8	15.1	11.4
Trickling filter loading, mgad.	3.67	5.67	2.67
Lb. B.O.D. per acre-ft. per day	830	1,640	510
B.O.D. data, ppm.:			
Raw sewage	198	334	127
Primary effluent	129	267	88
Filter effluent	32	57	12
Final effluent	25	55	12
Per cent reduction, primary effluent to final effluent	80.6		
Per cent reduction, overall	87.3		
Nitrates in effluent, ppm.	1–2	5	0

Ponding at Decatur, Ill., was bad over about 5 per cent of the filter area during August, 1944, the month reported by Hatfield in answering the questionnaire. Rather bad ponding occurred at Decatur during the spring and early summer of 1945 due to a combination of heavy industrial wastes loading, undersize surface media, and silt accumulation in the filters after their flooding by the Sangamon River. Hatfield reports control of this ponding by systematic hosing of the entire filter area. Huffman (Dayton, Ohio) reports some ponding due to heavy load and some extra small particles of slag in the filter media. He states that ponding occurs near the surface and it is to the floor. It was desired to see the condition of the rock through its entire depth as this filter was badly ponded. This hole was dug on the west side of the filter near the periphery in the section that most readily ponds. It was found that every void was completely filled with humus sludge and slime. It seemed remarkable that any water could pass through at all. Some of the rock was quite small but this was not caused by disintegration but was probably due to the fact that all the rock in the filter was dumped from trucks on this one side and then spread out from there. These small rocks naturally remained where they were dumped.

ponding has on some occasions covered as much as one-half the filter area. Clogging seems to be in the top six inches of stone. The cause appears to be small voids between the stone, and rather heavy B.O.D. loading. As soon as cold weather appears the filter effluent becomes noticeably turbid.

"Chlorine has been used to control ponding with fair success, but has not been used the past two years. (Hand picking has also been done.) Chlorine is applied to the primary effluent. Settled sewage of average strength has a high chlorine demand and, therefore, night or protracted storm flows are chlorinated, an attempt being made to maintain a residual of 2 to 5 ppm. at the surface of the stone."

Spiess (Litchfield, Ill.) reports that ponding used to be a problem during the winter months, presumably due to milk wastes. Spiess used a road scarifier to give temporary relief. During the past few years chlorination of settled sewage has been practiced from April to October, resulting in a "clean" filter to enter the winter period, thus eliminating difficulty from ponding.

Beamesderfer (Lebanon, Pa.) reports that ponding of filters occurred about four times during each of the past winters, and about 50 per cent of the filter area was clogged at the surface. He states:

"The cause was carelessness in skimming and squeegeeing the Imhoff tanks, thereby sending too much settleable solids over the weirs, overloading the filters. After four years of educating the operators, I proved to them that the best method of working the Imhoff tank is to shut off the tank and allow the disturbed settleable solids at the slot line to settle before putting the tank into service. This winter is the first winter in the history of the plant that the filters did not clog."

Lantenbach (Plymouth, Wis.) and Doyle and Dubay (Pontiac, Mich.) indicate that ponding is effectively remedied by going over the ponded area with a crowbar. Slight ponding at Clinton, Ill., is corrected by use of a pick, according to Corrington. Resting the filter is reported by Shick (Van Wert, Ohio) and Craig (Pontiac, Ill.) as the best remedy they have found for ponding.

The above experiences with ponding just about run the gauntlet of causes and remedies. It is axiomatic that an operator who experiences ponding difficulties should study his plant and the sewage to determine the contributing causes, and then take whatever steps are possible or practical to eliminate or control the causes so that it will be unnecessary to apply remedies. This advice is simple to give, but unfortunately its execution is not always readily attained. The author might add here that chlorination has proved very effective at several Illinois plants where filters were badly ponded due to heavy overload from milk wastes. Unless ponding was very deep chlorine dosages of about 10 lb. per 1,000 sq. ft. of filter proved effective. At Marissa, Ill., where the filter was completely ponded due to milk wastes, the ponding was brought under control by sprinkling HTH on the filter at the rate of about 8 lb. available chlorine per 1,000 sq. ft. After a couple of days the ponding was under control and the stability of the plant effluent increased from less than 1 day to 10 days, within about one week. Steps were then taken looking toward better control of wastes at the milk plant.

Occasional moderate doses of chlorine have been found of value at some plants in controlling excessive surface growths, and many plants have experienced better operation when a small continuous or semi-continuous chlorine dosage is applied to the settled sewage. This tends to keep the filter open and puts it in better condition to enter the winter period when more solids accumulate in the filter.

Nozzle Clogging

Every plant operator does a certain amount of maintenance in keeping filter nozzles clean. In a small plant the time consumed in nozzle cleaning usually is not great; in the large plants, however, this is usually an item of some magnitude.

Schaetzle (Akron, Ohio) reports that it requires 48 man-hours a week to keep nozzles clean and do the necessary weekly flushing of distribution laterals on 14 acres of filters. He reports that it would require two or three times that amount of work to keep nozzles clean if a 20-mesh, water spray cleaned, vertical traveling screen were not in use on the settled sewage.

A number of other plants have settled sewage screens of one kind or another. Green (Bemidji, Minn.) has installed a 30-in. long conical screen of ¼-in. mesh in the primary effluent outlet. This screen is cleaned daily and no trouble with nozzle clogging is experienced. Barnes (Bowling Green, Ohio) reports that a ⅜-in. mesh settled sewage screen, while effective, does not entirely eliminate nozzle clogging. A 3-mesh screen, cleaned weekly, saves Corrington (Clinton, Ill.) a lot of work cleaning nozzles. Hatfield (Decatur, Ill.) uses a ¼-in. mesh settled sewage screen effectively, but he reports it causes some grease separation on the surface of the dosing tanks. Hatfield designed a non-clog nozzle which greatly reduced his cleaning problem, as did Beamesderfer (Lebanon, Pa.). Pinney (Fargo, N. Dak.) uses a 5/16-in. mesh screen ahead of the dosing tank, and nozzle cleaning requires 1¼ man-hours daily. Simonton (Griffin, Ga.) reports good results with a ¼-in. mesh screen. Craig (Pontiac, Ill.) finds a ¾-in. mesh screen most satisfactory. Shick (Van Wert, Ohio) reports a ¼-in. mesh screen just about eliminates nozzle clogging if properly handled. Spiess (Litchfield, Ill.) is a "dissenter" regarding the value of a settled sewage screen. He discarded a ⅜-in. mesh screen because he experienced more trouble cleaning it than orifices. Sperry (Aurora, Ill.) sums up the matter by commenting that he would like to install a settled sewage screen, but has not been able to find a way or place where such a screen could be used.

Huffman (Dayton, Ohio) reports that a 50 to 60 per cent stoppage of nozzles occurs when the direction of flow is changed in the Imhoff tanks. He explains that the suspended solids load is considerably greater than the design capacity of the Imhoff tanks, the plant hydraulics are rather "tricky" since the secondary units were added in 1938, and plant personnel is limited, all of which are involved in this problem. He adds:

"Stop logs are provided to keep scum and other material from the idle effluent channel but on peak flows it is very easy to raise the water level sufficiently to allow material to pass over the scum boards, consequently during a four-week period considerable scum collects in the idle effluent channel and this passes on to the filters 'with a bang' when the direction of flow is changed."

In summary, it can be stated that nozzle clogging is a universal problem to a widely varying degree, and the use of settled sewage screens generally is reported to be of considerable assistance in its control. Most operators contributing to this summary indicated that nozzle cleaning is a daily chore.

General Cleaning

From the questionnaire returns it appears that the periods between cleaning of dosing tanks and distribution systems vary from about once weekly to about once annually. Green (Bemidji, Minn.) reports distribution arms are flushed daily, Alikonis (Bloomington-No mal, Ill.) reports a weekly cleaning schedule, while Huffman (Dayton) and Winfrey (Des Moines) indicate the filter distribution system at their plants has never been flushed.

Distributor arms on rotary distributors are normally flushed by merely opening the gates on the ends of the arms one at at time, but the problem is somewhat different at Fort Dodge, Iowa, as described by Magennis in his 1943-44 Annual Report:

"On June 3 the influent lines and distributor arms of filters No. 1 and No. 2 were cleaned with a six-inch auger on sewer rods. A considerable amount of accumulated grease was removed which had been retarding the flow so much that it backed up into the primary clarifiers and overflowed the weirs, permitting large quantities of grease and other floating material to flow out onto the first stage filter beds which were already badly ponded. Large pieces of grease were also removed from the center columns of all four distributors. This remedied the condition."

Johnson (Elgin, Ill.) reports:

"Our procedure for flushing out the filter distribution system, once weekly, is to first remove the end nozzle of each lateral. The two main header drain valves are then partially opened and left open until each dosing tank has discharged three or four times. Thus, the distribution system is largely drained before each siphon discharges, allowing air to be entrained which provides the effective flushing action."

Hatfield (Decatur) flushes the distribution system daily, also by opening the drain valve, allowing the system to partially fill with air, then closing the drain valve and obtaining good flushing action when the siphon discharges. From Hatfield's vivid description, this method of flushing the distribution system really gets results.

While most operators reported that underdrains are not flushed out, Beamesderfer (Lebanon, Pa.) and Har (McPherson, Kan.) indicated that the underdrains are flushed out twice yearly with a high pressure hose. Shick (Van Wert, Ohio) flushes out underdrains on alternate years. Corrington (Clinton, Ill.) reports the underdrains were flushed out during the first year of operation due to rock dust accumulations. Mackin (Madison, Wis.) flushes underdrains annually by attaching a self-propelling nozzle to a 1½-in. hose.

Psychoda Flies

Probably no nuisance problem in sewage treatment has been wider discussed than that of control of the insect *Psychoda alternata*. Of the plants contributing to this summary, 21 have had or still have a filter fly problem. At the remaining plants no problem of magnitude was reported.

The adult *P. alternata* lays its eggs in the filter growths. The larvae hatch in about 48 hr. and develop into adult flies by the 15th day. The larvae are ravenous eaters, and utilize the growth on the filter media as their source of food. In a heavily infested filter they may almost denude the film from the surface media; however, this is not too common. There is considerable thought that the larvae are beneficial in helping keep a filter loose and open, which is reasonable considering their food source and their huge number. The unfortunate

fact is that the larvae will reach adulthood, and during filter rest periods the flies may leave a filter in great numbers.

The most common method of filter fly control is that of flooding the filters every 7 to 14 days for a period of 24 to 36 hr. This drowns the larvae and may also flush out some eggs. This frequency of flooding is within the development cycle of the fly, which is necessary to achieve results. Nine of the contributors to this summary use flooding for fly control with results varying from good control to minor benefit. Moore (Albemarle, N.C.) indicates that some odor is present after 36 hr. of flooding. Spiess (Litchfield, Ill.) states flooding every ten days helps a lot, but he does not consider it the answer due to the necessity of his discharging 0.5 mg. of primary effluent to the outlet while the bed is flooded. He also indicates that snails and worms float to the surface and result in a bad odor nuisance, which is now effectively controlled by chlorination of the settled sewage.

Chlorination is also utilized in attempting filter fly control, again with reports of both successful and mediocre results. Magennis (Fort Dodge) reports that chlorination has been tried for filter fly control with no particular success. Mackin (Madison) reports that some fly control seems to be realized by chlorine dosage of 6 to 15 ppm. to the settled sewage, which is applied primarily for odor control. He describes chlorination as moderately successful for filter fly control at Madison.

Allison (Corpus Christi, Texas) reports successful use of chlorination combined with recirculation in controlling flies, odors, and slime growth. His interesting comments follow:

"When 1,000 gpm. recirculation was started, the prechlorination rate was 850 lb. per day. Prechlorination (ahead of primary tanks) at a 25 per cent higher rate gave very little odor control. Five hundred pounds per day (approximately 6 ppm.) postchlorination (following filters) gave excellent results in stopping complaints from odors, eliminated 3½ hours of daily cleaning of final clarifiers, and stopped *Psychoda* fly nuisance. Railroad engine shops alongside the plant were contemplating moving away because of the flies interfering with workmen. No complaints have been received since this control was started.

"We can kill larvae by increasing chlorine residual during the night recirculation. Complete control is obtained by returning to the primary clarifiers 1,000 gpm. from the bottom of the secondary clarifiers. This carries a chlorine residual during minimum flow at night and carries sufficient residual to the filters to kill fly larvae.

"Continuous dosage (application of sewage) keeps flies at a minimum. Shut off dosage on a sunny day and within two hours you can note the increase in flies. On a warm sunny day shut a well-coated filter down and you can observe the fly larvae clean the surface film at the rate of 4 square inches in 30 minutes, and double their size. Continuous dosage seems to wash the larvae through the filter just previous to their forming into the adult fly."

Hager (San Bernardino, Calif.) reports a fly problem from January to May. He reports that the insects are kept at a minimum by weekly dosage of the filter influent with 300 lb. of chlorine over an 8-hr. period in the early morning hours when the flow is low. This gives a residual of 0.10 ppm. at the dosing tanks.

Downes (Plainfield, N.J.) reports *Psychoda* have not been a problem since continuous flow over the entire filter area has been maintained by pumping back filter effluent to maintain a 7 mgd. flow rate to the filters (3.9 mgad.). He reports no adult flies on the wing as long as the flow continues, but reminds that they are under the surface stone and emerge if the flow is stopped for even a few minutes. This brings out the advisability of adjusting the distribution, if possible, to avoid dry areas or areas only slightly wetted, which give the flies their opportunity to take wing.

Regarding the possible effectiveness of the small water springtail, *Achorutes viaticus*, in controlling filter flies, replies ranged from completely negative to one positive. As most operators are aware, the *Achorutes* is a small, blue-black, wingless insect which can jump several inches by means of its so-called "springtail." Some filters have been naturally infested with the *Achorutes*, while a considerable number of filters have been seeded with them by transferring media from an infested filter. Not all efforts at transfer have been successful. Downes (Plainfield, N.J.) advises that the *Achorutes* gave no assistance in *Psychoda* fly control; conversely, Corrington (Clinton, Ill.) reports that since seeding the filter with springtails, less and less trouble with filter flies has been experienced until they are now present only in small numbers. Johnson (Elgin) reports *Psychoda* flies were a nuisance, and in 1931 *Achorutes* were transplanted from Madison, Wis. In two years, seemingly with the increase in numbers of springtails, the fly nuisance abated. The flies are now present in greatly reduced numbers and they remain in the filter area. Johnson cautions that he is not sure whether the springtails are entirely responsible or if other conditions were partially responsible for the decrease in fly population. The *Achorutes* survived the filter rehabilitation at Elgin in 1941. Mackin (Madison) reports that the *Achorutes* are occasionally furnished to others by request. He indicates that they may be of some benefit, but that he does not feel their benefit is substantial.

Harr (McPherson, Kan.) indicates he treats the filter with creosote periodically and burns flies with a kerosene torch in the mornings. He did not indicate the effectiveness of these practices. Beamesderfer (Lebanon, Pa.) reports that the rough stone walls of the filters are sprayed with a 3:1 mixture of crankcase oil and kerosene attracting the flies which come into contact with the oil, stick fast and die. Then, he reports, the filters are by-passed for 4 to 5 days to dry out the film on the beds, which is followed by increasing the rate of sewage application to flush out the dried film and unload the beds. Beamesderfer reports that these procedures keep filter flies under control, but he did not indicate the frequency of this control measure. Outlet stream requirements at most plants would not allow any such period of by-passing secondary treatment.

Other chemicals, such as pyrethrum and ammonia, have been used in attempts at filter fly control, usually with indifferent results. Published results of plant scale experimentation with the new insecticide, DDT, in the control of *Psychoda* flies are awaited with interest. The author has had the pleasure of reviewing one interesting paper based on an entomological study of *Psychoda* larvae and flies as affected by DDT, and it is hoped that this and other worth-while papers on the subject will be made available soon. (See *Sew. Wks. Jour.* 18, 1 (March, 1946) pages 181 and 208.) Alikonis (Bloomington-Normal, Ill.) has done considerable work with DDT, and he indicated at the 1945 Illinois Sewage Works Operators' Conference that he has found DDT very helpful in controlling the adult flies.

Odors

Odors are usually not a problem if filters are operating well and receive fresh sewage; if a septic sewage is applied, however, a considerable nuisance may result from the release of odorous gases as the sewage is sprayed onto the filters. Needless to say, all odors at a plant are not necessarily released at the filters.

Of the plants contributing to this review, many experience odor problems. Schaetzle (Akron) reports they have had 25 to 30 damage suits because of odors and gnats and have lost all that came to trial. He indicates that cleanliness is the only precaution they can take against odors as no provisions are made for the use of chlorine. He also indicates that he is obliged to lagoon practically all sludge, most of it in an undigested state, which "does not reduce odor complaints."

Eleven of the contributors reported use of chlorination for odor control. Both pre- and post-chlorination are practiced at Bowling Green, Ohio, by Barnes. Odor control is very important at Bowling Green since the plant is located along a main thoroughfare and close to a university and airport. Barnes indicates that 150 lb. of chlorine are used daily. Allison's practice at Corpus Christi of recirculation and chlorination of filter effluent is described in the discussion of *Psychoda* fly control. Allison indicates the chlorine residual in the recirculated flow at 6:00 a.m. is about 1.5 ppm. The Corpus Christi plant is 3,000 feet from the center of town, and no odor complaints have been received since practicing this method of control. Downes (Plainfield, N.J.) chlorinates the raw sewage for odor control, as does Mattson (Oconomowoc, Wis.). The latter applies chlorine at 4 to 7 ppm. when pea canning is in progress. Lantenbach (Plymouth, Wis.) applies 20 lbs. of chlorine daily to the raw sewage during the hot months when the local cannery is discharging chemically pretreated wastes to the municipal sewers. Shick (Van Wert, Ohio) applies 60 lb. chlorine per day from June to September, to the raw sewage at the lift station one mile from the plant, to prevent the sewage from becoming septic.

Mackin (Madison) adds 6 to 15 ppm. chlorine to the settled sewage for odor control. Beamesderfer (Lebanon, Pa.) applies 2 ppm. chlorine to the Imhoff tank effluent for odor control. Also, dissolved oxygen tests are made on the raw sewage and when no D.O. is present, recirculation is started at a 0.60-mgd. rate to the raw sewage. Beamesderfer reports this practice as very effective in controlling odors. Magennis (Fort Dodge) adds about 16 ppm. of chlorine at the dosing tanks for odor control. Fort Dodge is another municipality which has paid rather heavily for settlements, judgments, and legal services in lawsuits and claims due to alleged odors. Magennis states:

"Odors are not nearly the problem they used to be due to the fact that the packing company waste is now being received in a much fresher state than it was a few years ago when some of the material was held by them for as long as 24 hours before it was dumped, which usually occurred at night during the light flows. Since the construction of a main catch basin with continuous grease skimming equipment, the material is fed to the sewers about as fast as it is produced. This had alleviated much of our odor trouble. We do, however, at times have a characteristic packinghouse odor

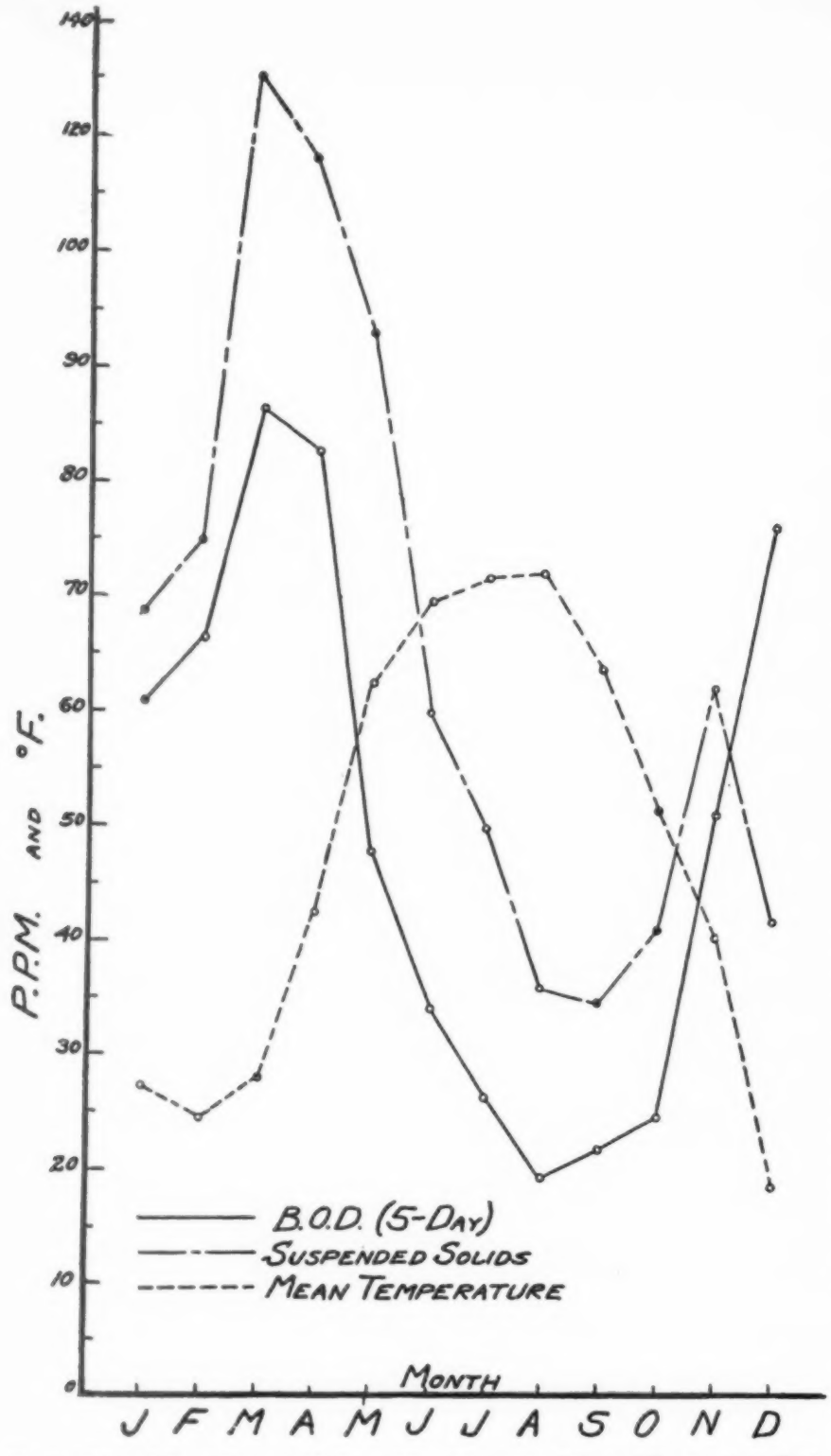

Fig. 1.—Filter Effluent Data at Madison, Wis., Illustrating Effect of Temperature Variation (1944 Monthly Averages).

which comes off our preaeration tank which is used for grease removal. The only other odor we have comes from the filters and is more or less a musty odor. Both of these odors can be controlled by the use of liquid chlorine."

Recirculation of final effluent is also used as an odor control measure at Fort Dodge. When the last raw sewage pump stops, a 1,000-gpm. recirculation pump automatically starts, which helps reduce odors emanating from idle filters, particularly during the night. This recirculation usually takes place between 1:00 and 6:00 a.m., during which time the recirculation pump operates approximately 50 per cent of the time.

Hager (San Bernardino, Calif.) reports that preaeration eliminates all hydrogen sulfide odors at his plant. Preaeration, if in sufficient amount, can prove very helpful in odor control in addition to its substantial assistance to the efficiency of primary sedimentation units.

Sperry (Aurora) indicates that odors are generally not a problem, as the hydrogen sulfide content of the settled sewage is consistently below 1 ppm., which is not enough to cause complaint. He does indicate, however, that many times during the summer a noticeable taint of hydrogen sulfide can be observed across the river from the plant in the quiet of the evening. This is still a function of the weather in the typical way, *i.e.*, the odors tend to stratify and follow ravines on quiet, cool evenings.

With the exception of Shick's practice at Van Wert, none of the operators reported chlorination up-sewer from the plant. Chlorination ahead of long force mains is definitely helpful, both for odor control and to permit delivery to the plant of a sewage which is not rendered much more difficult to treat due to its septicity. Flushing flat, sluggish sewers periodically in warm weather also is helpful in delivering a fresher sewage to the plant for treatment, at the same time assisting in odor control.

Unloading

In general, solids tend to accumulate in low rate filters, particularly during the winter months when biological activity is reduced. These solids slough off periodically, usually in the spring when biological activity increases, but at some plants in both spring and fall. The sloughing period varies considerably in length and intensity at the plants covered in this summary, from a few days at Des Moines to as long as three months at Elgin. Several operators reported more or less continuous unloading. Downes reports continuous unloading at the Plainfield filters since the recirculation practice was started, and Hatfield (Decatur) also reports more or less continuous unloading at a plant where no recirculation is practiced. Allison (Corpus Christi) reports filter unloading for four or five days after a temperature drop to 35° or 40° F.

The filter unloading problem assumes greater proportions at Elgin, Ill., where Johnson reports unloading continues from April to June with the humus load during unloading from 300 to 800 per cent of normal. Sludge storage facilities are taxed during the sloughing period, and the filters do not recover to function normally until July. A sludge lagoon helps to overcome the sludge storage element of this problem at Elgin.

At Galesburg, Ill., Hunt reports 35 to 50 per cent more humus load during the two months filter unloading period. At Galesburg, with digesters loaded to capacity, this results in excessive gas production with the gassing rate sufficient to cause a thin digested sludge. Mackin (Madison) reports 3 to 6 weeks unloading in the spring and 2 to 3 weeks in the fall, with a humus load of 300 per cent above average resulting in the overloading of digesters.

Winter Operation

Less than half of the plants included in this summary reported any particular difficulty in winter operation; the majority of plants, however, do take some common sense precautions to avoid damage to equipment or interruption of operation.

An almost universal procedure at plants having intermittent dosage, where freezing temperatures are encountered, is that of partially opening drain valves in the laterals of fixed nozzle systems to lower the sewage level in the vertical risers between doses, and thus reduce opportunity for freezing in the risers. With rotary distributors, the drain valve in the distributor base is usually opened slightly to prevent freezing in the distributor arms.

In severe weather a rotary distributor may be interfered with by ice building up in a ring (or part of a ring) around the filter wall, or in circular ridges on the bed. A ¾-in. hole drilled in the end gate of the distributor arms to direct a flow of sewage

against the wall has been found helpful at some plants in reducing ice formation around the filter wall. (Tap the hole so a plug can be inserted during warm weather.) Formation of ice around the filter walls is a problem at Plymouth, Wis., and Lantenbach reports that the 4-ft. arm extensions on the distributor are removed and ice is chopped when necessary to keep the distributor free to operate. Corrington (Clinton, Ill.) corks the last four orifices on the distributor arms to help control ice formation around the outside wall, and chops away this ice formation when necessary. During continued sub-zero weather Corrington blocks the distributor in one position. Barnes (Bowling Green, Ohio) reports that ice builds up sufficiently in extreme cold weather to stop the distributor arms, which are a minimum of 9 in. above the media. During extreme cold weather Barnes by-passes the filters, and prevents the final tanks from freezing by passing the flow through them by way of the handhole plates in bases of the rotary distributors.

Johnson (Elgin) reports:

"Since rehabilitation of the filters (in 1941) no ice formations have developed. In previous years, with weather comparable to the cold winter just experienced (1944), ice would form to heights of 2 to 3 feet. Large surface stone used in repairing the beds is considered the main contributing factor in correcting this condition.

"To minimize freezing in winter operation, dosing tanks are covered with planking, siphon piping on the exterior of the dosing tanks is housed and insulated with straw, nozzles are inspected twice daily, and colored warning lights connected to the dosing tank counters are provided so that the night watchman can observe from the office building that the filters are operating in their proper sequence."

Magennis (Fort Dodge) reports that packinghouse wastes raise the temperature of the raw sewage so that freezing is no problem at the first stage filters, and is of consequence at the second stage filters only when the air temperature is zero or lower. Magennis further reports that the most persistent freezing on the filters occurs at the periphery of the beds over the vertical ventilation stacks. The wall and ventilation stacks extend about 1 ft. above the media and this serves as a "snow fence." The nozzle spray coats this snow and eventually forms ice which keeps building up until it must be removed with a pick. To minimize this difficulty, the outside orifice on each distributor arm is plugged so the spray will not reach the wall. This has solved that particular problem. During prolonged cold weather, the spreader plates over the distributor orifices are lifted, concentrating the flow from each orifice in a confined area around the filter. Magennis reports this practice has aided a great deal in maintaining filter operation during extreme cold weather.

Winfrey (Des Moines) and Spiess (Litchfield, Ill.) report use of recirculation to minimize freezing at the filters by cutting down the dosing cycle during low flow periods. Winfrey also cracks open the end gates of the distributor arms.

Green (Bemidji, Minn.) reports no ice problems (although his city frequently reports the coldest temperature in the nation) due to the housing of the filter. Pinney reports no ice problem at the Fargo, N.D., filters for the same reason (Figures 4 and 5). It goes without saying that Hager (San Bernardino, Calif.) and Clark (Huntington Beach, Calif.) have no winter operation problems related to ice formation!

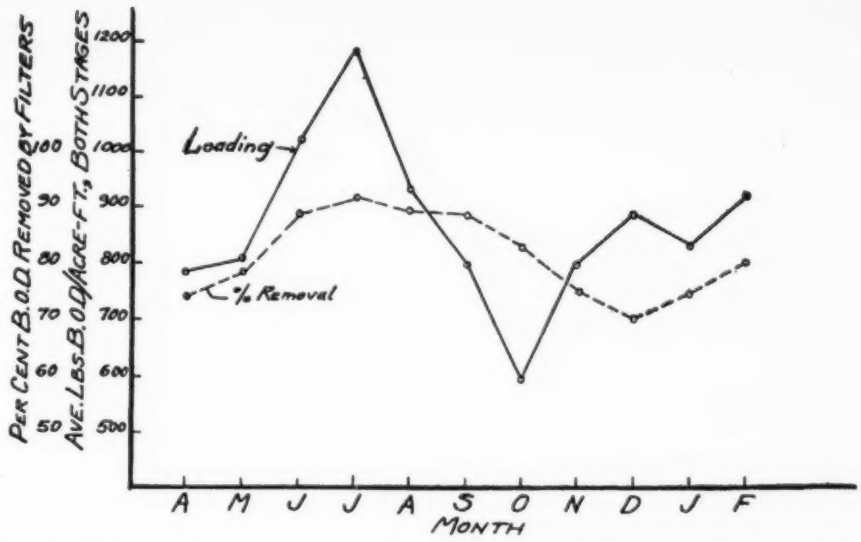

Fig. 2.—Effect of Temperature Variation on Efficiency of Two-Stage Filters at Fort Dodge, Iowa (1943-44 Monthly Averages).

Unusual Problems

An unusual problem is reported by Magennis at Fort Dodge, Iowa. He describes it as follows:

"For the last fiscal year an average of 6.8 cu. ft. of grit was removed from the detritor daily. Three-fourths or more of this grit was composed of tiny snail shells which were pumped with the humus sludge from the intermediate and final clarifiers. These snail shells came from the filters. Large quantities of them pass through the detritor, settle in the primary clarifiers, and are pumped with the raw sludge to the digesters. In 1942, after four years of operation, two of our digesters were drained for inspection. In the bottoms under the discharge openings into the digesters were found piles of sand, grit and snail shells. These piles sloped down on each side and toward the sump in the center of the floor. This collection of material covered the lower heating coils nearly half way around each digester. This accumulation reduced the digester capacities about 10 per cent. Incidentally, the removal of this material was a slow and tedious process, taking over a month for completion. It was accomplished by the use of the positive displacement sludge pumps and a fire hose. Two or three complete stoppages of the sludge line were encountered before the job was completed."

Spiess (Litchfield, Ill.) reports a difficult scum problem in the digester, with the scum layer accumulating to depths of 6 to 8 ft., which he attributes in part to the large quantities of snail shells flushed from the filter and pumped to the digester with the humus sludge.

An unusual problem at Corpus Christi, Texas, is that of galvanic and other corrosion of metallic equipment due to the high chloride content of the sewage, which results from infiltration of salt-bearing ground waters. Allison reports that the chloride concentration reaches 3,200 ppm. during the night flow, but this causes no operational difficulty other than the corrosion.

Temperature Effect

Temperature is an important factor in the functioning of any biological process, and the trickling filter is no exception. If a filter receives a fresh sewage within its loading capacity, it normally produces its best effluent during the warmer months. This is borne out by the questionnaires returned, and was particularly commented upon by thirteen operators. Several operators indicated, however, that they could not observe any decrease in filter efficiency during the winter months.

Sperry (Aurora), Alikonis (Bloomington-Normal), and Craig (Pontiac, Ill.) all note no particular decrease in efficiency during winter operation. Conversely, a decided drop in efficiency is reported at Akron, Ohio, Albemarle, N.C., Bowling Green, Ohio, Decatur, Ill., Dayton, Ohio, Galesburg, Ill., Griffin, Ga., and Pontiac, Mich. Downes (Plainfield) reports that the effluent stability drops from 10 days in summer to 4 to 5 days during February, March and early April. At Lebanon, Pa., Beamesderfer reports that the effluent stability drops to 50 per cent during the winter. The cold can penetrate the Lebanon filters very deeply as the filter walls are constructed of large stone laid with open joints. Hager (San Bernardino) reports a decrease in filter efficiency when the temperature dropped during the winter of 1944.

Mackin (Madison, Wis.) reports a decided drop in filter efficiency during the winter months, and experiences at Madison are graphically illustrated in Fig. 1, which shows B.O.D. and suspended solids in the filter effluent by monthly averages, and mean monthly air temperatures, for the year 1944.

Magennis (Fort Dodge, Iowa), reports a 25 to 30 per cent drop in filter efficiency during the winter months. Fig. 2 was plotted from data contained in the Fort Dodge 1943-44 annual report, the loadings indicated being based on the monthly average pounds of settled sewage B.O.D. per acre-foot of volume of both stages of filters. The final effluent B.O.D. was 44 ppm. in July when the overall loading was 1,180 lb. per acre-foot, and the effluent B.O.D. was 188 ppm. in December when the overall loading was 890 lb. per acre-foot. The per cent B.O.D. removals indicated in Fig. 2 include that removed by filters and secondary clarifiers.

Recirculation

Recirculation has received greatly increased attention in recent years with the development of high-capacity filters. Its application has not been restricted to high-capacity filters, however, as quite a number of plants of standard rate design have ap-

plied recirculation with good effects for a number of years. Recirculation applied to standard rate filters has resulted in their ability to handle considerably higher loadings without ponding, has increased efficiency of existing plants, and has assisted greatly in the control of odors and *Psychoda* flies.

Recirculation is applied in a number of combinations. Filter effluent, final tank underflow, or final effluent may be recirculated to a point either ahead of the primary tank or directly ahead of the filter.

Allison (Corpus Christi) authored an interesting article (*Sew. Wks. Jour.* 4, 729-733 (1943)) regarding trickling filter operation as practiced at Corpus Christi. Among other things, he points out that with the original motor-driven distributors the importance of continuous operation to maintain high constant efficiency was proved. By careful adjustment of distribution, and with continuous distributor operation, average B.O.D. reductions exceeded 90 per cent. When the load increased some plant additions were made, among them a change in rotary distributors to the two-compartment arm reaction type. The average B.O.D. reduction then dropped to about 80 per cent due to interruption of operation of the reaction-type distributors during the low night flows. By recirculating 1,000 gpm. of underflow from the final settling tanks, the reaction distributors are kept in constant motion, and the average B.O.D. reduction increased to 90 per cent and above. A major advantage of recirculation at Corpus Christi, in conjunction with the chlorination of the filter effluent, is in controlling odors and *Psychoda* flies, as described elsewhere in this summary.

A classic example of the effect of recirculation in increasing filter efficiency is the experience of Downes at Plainfield. The average sewage flow is 4.25 mgd., and filter effluent is recirculated to maintain a constant rate of 7 mgd. to the filters, which is the maximum capacity of the fixed-nozzle distribution system at mean head in the dosing tank. Motor-operated butterfly valves on the dosing tank outlets have a 35-second cycle from zero to full head, which constantly changes the conformation of the spray thus covering all parts of the filter area. Reference to Tables I and II indicates that with an average B.O.D. load to the filters of 1,080 lb. per acre-foot per day an average B.O.D. reduction of 92 per cent was obtained by the filters, and an over-all reduction of 97.8 per cent. As previously discussed in this summary, recirculation at the Plainfield plant also effectively controls *Psychoda* flies, and results in continuous filter unloading.

Hager (San Bernardino, Calif.) recirculates 20 per cent of the plant effluent back to the dosing tanks in order to reduce the dosing cycle and increase plant efficiency. He reports this practice also assists in odor control. Spiess (Litchfield, Ill.) recirculates continuously from the final tank to the raw sewage wet well, and he reports that this practice improves the effluent, aids in filter fly control, and helps keep down ice at the filter during winter operation.

Humus Sludge

Most of the smaller plants reported that humus sludge accumulations are removed from the final settling tanks, by pumping or gravity flow, from once to six times daily depending upon local factors. The larger plants in general reported longer or more frequent periods of humus pumping. Humus sludge is pumped eight hours daily at Akron, and continuously at Dayton and Fort Dodge. Humus sludge is either pumped back to the raw sewage and the combined sludge from the primary tank pumped to the digester, or the humus sludge is pumped directly to the digester. The former practice is by far the more common.

Two of the contributing plants reported unusual practices in the handling of humus sludge, those plants being Albemarle, N.C., and Dayton, Ohio.

Moore (Albemarle) reports the interesting use of chemical precipitation of the filter effluent. Sufficient head is available so that the dosing siphon air piping is blocked and the flow is allowed to fill the dosing tanks and pass through the overflow to the distributors. The sewage flow to the distributors is thus reasonably uniform, making chemical dosage of the filter effluent much easier to control. Moore states:

"The need of chemical precipitation was not dictated by the continuous unloading of the filters nor the need for concentrating the final tank sludge. It is true that it helped both of these in our plant, but the main reason was to lower the suspended solids and B.O.D. so that the effluent could be passed into a small creek which dries up at times in the summer months. A considerably lower dosage of chlorine is needed to kill the bacteria in this chemical precipitation plant effluent and quite a saving is accomplished while having a purer effluent.

"We have tried ferric chloride, 'Ferrisul,' ferric sulfate, 'Ferri-floc,' 'Ferrichlor,' copperas, activated alum, and for the past several years we have been using alum only, without lime, as we have plenty of alkalinity added in our industrial dye wastes, along with plenty of sodium chloride.

"We are at present using an average dosage of 60 ppm.—our minimum dosage for domestic sewage runs around 30 ppm. Some of our dye waste will take dosages up to 150 ppm. to produce a suitable floc and then the color will remain at times. Considerable experimentation has been carried out with various dye wastes as to chemical dosages required. The flocculation period is 36 minutes per million gallons per 24 hours. (The average final settling period is 2.07 hr.)

"In answer for data on the per cent solids of the final tank sludge after chemical precipitation, we are submitting the following averages: per cent moisture, 96.2; per cent dry solids, 3.8; per cent volatile matter, 51.7. Considerable trouble was experienced when pumping this chlorinated sludge directly to the digesters. By keeping a graphic record of the per cent moisture at different elevations in the sludge tanks, we could see the effects the secondary sludge had on settling and digestion. Curves on per cent digested at these various elevations within the sludge tanks were not satisfactory, and therefore this secondary sludge is drawn directly to the head of the plant and mixed with the incoming sewage. Our digesters are kept at a temperature of 100° F. for faster digestion —15 days—with a quicker settling period."

Moore also reports that the chemical dosage is based on the alkalinity rather than on the variable pH. Digester supernatant is also discharged to the flocculation tank and treated chemically.

Huffman (Dayton) reports that the return of humus sludge has resulted in a heavy load to the Imhoff tanks. A year's experimentation was undertaken in the laboratory to devise effective methods of sludge thickening so that the humus sludge could be pumped directly to the digesters, relieving the Imhoff tanks of this extra load. The results of this experimental work as performed by R. Calihan, Plant Chemist, follow:

"The solids concentration of the humus sludge from the secondary clarifiers varies from 0.1 to 5 per cent according to the time of the year (sloughing) and the technique of operation. This variation may occur even within a few hours operation, and so introduces a delicate problem for chemical treatment.

TABLE VI.
Experimental Treatment of Humus Sludge at Dayton, Ohio

Jar Number	Treatment	Final pH	Settling and Compaction	Supernatant Quality	Rising Time (hr.)
1 and 2	None	7.0	Poor	—	2*
3	5 min. mech. agitation	7.2	Good	Turbid	5+
4	10 min. mech. agitation 85 ppm. lime	8.4	Better than No. 3	Turbid	5+
5	10 min. mech. agitation 171 ppm. $FeCl_3$	6.8	Slower compaction	Clear	5+
6	10 min. mech. agitation 256 ppm. $FeCl_3$	6.4	Same as No. 5	Very clear	5+
7	10 min. mech. agitation 85 ppm. lime, 171 ppm. $FeCl_3$	7.0	Same as Nos. 5 and 6	Very clear	5+

*Rising of sludge began in 15 min.

"It was found by jar tests (Table VI) that mechanical agitation alone produces a good floc with subsequent rapid settling, leaving a supernatant having little or no sludge particles. This reaction could be accomplished by agitating the raw sludge as little as five minutes. Settling required another 10 to 30 minutes, depending upon the solids content of the sample. The sludge having received this treatment remained on the bottom of the jar approximately five hours. Room temperature for the tests was between 85 to 95 degrees F. Longer periods of setting may be expected at lower temperatures due to less active bacterial decomposition of the sludge.

"The supernatant of the mechanically agitated sludge always increases in turbidity due to the elutriation phenomenon which occurs. This would indicate a higher B.O.D. for the supernatant and would probably be dependent upon the length of time the sludge was agitated. Tests were run for B.O.D. of supernatant after the sludge was agitated for different lengths of time, and the following results were obtained:

	5-Day B.O.D. (ppm.)
Untreated sludge	323
Sludge agitated 10 min.	423
Sludge agitated 30 min.	603
Sludge agitated 45 min.	700

"These figures support the contention that longer agitation increases B.O.D., and therefore introduces another operation problem, that is, where should this supernatant liquor be placed in order to eliminate the high oxygen demand it has required from the sludge it washed?

"The alternative to the production of increased B.O.D. (of supernatant) by continued agitation is undoubtedly proper timing of the flocculation to produce compact settling without causing a transition of the

soluble material in the sludge itself to the water in which it is immersed.

"Another method of clarifying the supernatant of solids and high oxygen requirement is mechanical agitation with addition of chemicals. This, too, requires rather careful control in that the chemicals necessary for proper precipitation of the dissolved and suspended solids are dependent upon the solids content of the incoming sludge which, as previously stated, is quite variable. From tests already conducted, it was found that rather high dosages of chemicals were necessary to produce a clear supernatant with a pH of 7.0. For instance, 10 grains per gallon ferric chloride and 5 grains per gallon lime were required to get a clear supernatant and even higher dosages of alum were added for the same results. At present, tests remain to be made to determine the B.O.D. of supernatant from the chemically clarified sludge."

Based upon these results, a humus thickening tank 78 ft. x 10 ft. x 10 ft. water depth has been constructed at Dayton. Mechanical flocculation is provided, and the sedimentation period is 3.83 hr. The tank will operate continuously and is equipped with a sludge collector. The supernatant from this tank can be discharged to the plant effluent, back to the filters, or pumped to the garbage grinder to supply the water needed there. Huffman states it was hoped to obtain 5 per cent sludge from this installation and pump it directly to the digesters. Operation results are not yet available.

Industrial Wastes

No summary of trickling filter operation experiences would be complete without some reference to industrial wastes. Trickling filters are extremely versatile and are capable of providing treatment for a wide variety of industrial wastes provided loading limitations are respected, and provided the waste in question is not in too great concentration, is not in toxic concentration, and that it contains the necessary nutrient material to sustain the biological life on the filter media. Many industrial wastes for which separate treatment is expensive and often impractical are treatable in combination with domestic sewage, provided that precautions are taken against shock loads and provided the industrial wastes are not too great a percentage of the combined flow. Many difficult industrial waste problems have bowed to trickling filters, properly applied.

Eighteen of the plants contributing to this summary receive industrial wastes of consequence. Barnes (Bowling Green, Ohio) reports that the population equivalent from tomato cannery wastes often triples the domestic load. The tomato wastes are received as shock loads after pretreatment to the extent of a fine screen and grit chamber. The plant was designed for a high population equivalent and effective treatment is provided. Schaetzle (Akron) has rubber wastes to contend with, and his interesting report on this problem is contained in *Sew. Wks. Jour.* 17, 497-501 (1945). Hatfield (Decatur) reports an industrial wastes loading from a large corn products plant of 60,000 to 100,000 population equivalent, with peak loads of 160,000 on some days. Through considerable work with the industry, Hatfield succeeded in having recovery procedures installed by the industry. With careful operation by the industry the industrial wastes population equivalent at Decatur can be kept to less than 100,000. The Decatur plant contains activated sludge units in addition to the trickling filters.

Winfrey (Des Moines) reports that 1 mgd. of packinghouse wastes are received at the plant, resulting in a large quantity of screenings to grind, much grease to skim and barrel, and heavy production of digester gas (over 2 cu. ft. per capita daily). He reports that a revenue of $16,346 from the sale of excess gas and $1,439 from the sale of grease was derived during the 1944 fiscal year. Mackin (Madison) reports that 2 to 3 mgd. of packinghouse wastes are included in the total daily flow of 12 to 14 mil. gal. The packinghouse wastes are pretreated. The trickling filters at Madison are used to treat the excess load above the capacity of the activated sludge process.

Magennis summarizes the industrial waste problem at Fort Dodge as follows:

"Contributors of industrial wastes include creameries, poultry houses, a serum manufacturing plant, a rendering company, and a meat packing plant which we usually consider as our sole contributor of industrial wastes because the others are of no particular magnitude. The packing plant contributes about 0.60 to 0.80 mgd. This is about 21 per cent of the total sewage flow. This waste contains about 68 per cent of the suspended solids loading on the plant and about 74 per cent of the B.O.D. load. The plant was designed for 7,700 lb. of B.O.D. per day and a population equivalent of 36,000. Last year the average daily load was 15,140 lb. of B.O.D., 12,350 lb. of suspended solids and a population equivalent of 89,060. The packing plant waste undergoes no pretreatment other than a final grease skimming process at the packing plant. Other than the terrific overload, the chief effect on treatment seems to be caused from large quantities of grease lost by the packing company. We have reclaimed and sold an average of 338 lb. of grease per day last year. (Total revenue from grease sales in the 1943-44 fiscal year was $2,697.) This grease tends to cling to the pipes, decreasing their capacities to the extent of nearly complete stoppage at times, especially in the suction pipe of the grease pit. The walls of the wet wells have to be scraped free of grease quite often. The walls of the control pit, which is ahead of the main lift station, are scraped at least once every two weeks. The grease accumulates here in such large chunks at times that they restrict the flow to the plant and by-pass it to the river. These large chunks are accumulations that have been freed from the inside of the sewer line between the control pit and the packing plant."

Magennis reports a population equivalent for the packinghouse wastes of 42 per hog killed, with a range by monthly averages from 25 to 64.

Simonton (Griffin, Ga.) reports cotton mill wastes are received with no pretreatment or control of the discharge rate. He also advises that oil and grease cause some trouble by forming a film on the filter media. Williams and Malone (Durham, N.C.) report dyes from hosiery mills are received after pretreatment with lime. They report no difficulty if the wastes are not discharged as shock loads.

Mattson (Oconomowoc, Wis.) notes that 40 per cent of the total flow is due to wastes from a condensery and malted milk plant. Pea cannery wastes of 60,000 to 240,000 gpd. are received seasonally without pretreatment. He states that the pea cannery wastes result in a heavy growth on the filter media.

Hager (San Bernardino) reports 1,000 gal. of gunk is discharged to the sewers periodically, leaving a distinctive odor throughout the plant which persists at the filters for many hours. Hager observes that the gunk probably affects the digesters, as does 1,000 gallons of chromic acid discharged periodically to the sewers.

Shick (Van Wert, Ohio) reports that installation of a rotary screen by a canning company has permitted his plant to handle this load without difficulty, together with a heavy milk wastes load. He also commented that tar and oil discharged from an artificial gas plant became so bad that the wastes had to be directed to the stream. The tar and oil filled the digester and almost completely destroyed the effectiveness of the filters. The latter units required six months to recover.

A LUBRICATION CHECK SHEET

By ROBT. C. URBAN
San. Engr., Corps of Engrs., War Department

THE Lubrication Check Sheet shown below will be of help in normal times of operation as well as when adverse conditions prevail.

There are three steps in setting up a lubrication check sheet.

1. Locate every piece of equipment needing grease or oil as a lubricant or as protection.

2. Study the manufacturers maintenance instructions to determine where and when to lubricate and what kind of lubricant to use. Inasmuch as many manufacturers have particular preferences in the matter of lubricants, this may lead to a large number of different types of lubricants and as many grease guns.

It may be much simpler to call in a lubrication engineer from any of the recognized oil companies and have him prepare a lubrication specification sheet for every point of lubrication you have listed.

In this way it may be possible to cut down on the number of oils and greases that will have to be stocked. As few as two oils and two greases may suffice.

3. Prepare the Lubrication Check Sheet following the general idea of the accompanying illustration. List all of the units needing lubrication, the necessary lubrication points, the type of lubricant recommended for each point. Allow space for date of lubrication and initials of operator performing the job.

There is no doubt that the Lubrication Check Sheet will become more and more important to the proper maintenance of operating equipment.

MASTER LUBRICATION CHECK SHEET

1945

GREASE: "HEAVY" - X CO. NO. 2 HEAVY DUTY
"CUP" - X CO NO. 31 CUP GREASE

OIL: "20" - X CO. NO. 341 S.A.E. 20
"90" - X CO. GEAR OIL 90

UNIT	FITTING TYPE	NO.		TYPE OF OIL OR GREASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SEWAGE PUMP HOUSE																
SEWAGE MOTORS (2) BEARINGS	PIN	2 EA.	G	"HEAVY"												
SEWAGE PUMPS (2) BEARINGS	PIN	2 EA.	G	"HEAVY"												
GREASE SEALS (2)	PRESSURE CUP	1 EA.	G	"CUP"	←		CHECK DAILY & ADD AS REQUIRED									→
VACUUM MOTOR BEARINGS	PIN	2	G	"HEAVY"												
VACUUM PUMP	SIGHT FEED	1	O	S.A.E. 10	←		CHECK DAILY & ADD AS REQUIRED									→
FLOAT RODS (2)	"SURFACE"	1 EA.	O	"20"	2 T M	1 AK	5 J M	6 J M								
SCREENINGS GRINDER																
GEAR REDUCER	PLUG	1	O	"20"	CHANGE 2 T M				CHANGE				CHANGE			
(" ")	PLUG	1	O	"20"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
LOWER SHAFT BEARING	PUSH	1	G	"HEAVY"	←		TWELVE STROKES DAILY									→
MOTOR BEARING	PIN	1	G	"HEAVY"	2 T M											
SLUDGE COLLECTOR																
GEAR REDUCER	PLUG	1	O	"90"	CHANGE 8 T M						CHANGE					
(" ")	PLUG	1	O	"90"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
SPROCKET BEARING	PUSH	1	G	"CUP"	GREASE WEEKLY								SEE WEEKLY CHECK SHEET			
MOTOR BEARING	PLUG	1	G	MANUFACTURERS SPECIAL	8 T M											
SLUDGE PUMP																
MOTOR BEARINGS	PUSH	2	G	"HEAVY"												
MAIN BEARINGS	PUSH	4	G	"HEAVY"	8 T M	1 AK	5 J M	7 J M								
ECCENTRIC BEARING	SIGHT FEED	1	O	"20"	←		CHECK DAILY & ADD AS REQUIRED									→
CROSS HEAD BEARING	"SURFACE"	1	O	"20"	←		CHECK DAILY AND KEEP PIN COVERED									→
GEAR REDUCER	PLUG	1	O	"90"	CHANGE 8 T M						CHANGE					
(" ")	PLUG	1	O	"90"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
CONNECTING ROD	GREASE CUP	1	G	"CUP"	←		GIVE SLIGHT TURN DAILY									→
TRICKLING FILTER																
BEARINGS	PIN	5	G	"CUP"	10 T M	5 AK	5 J M	14 J M								
ROTARY VENTILATORS (3)																
TOP BEARING	"CUP"	1 EA.	G	"CUP"												
BOTTOM BEARING	"CUP"	1 EA.	G	GRAPHITE MEDIUM												
HOT WATER CIRCULATORS (2)																
MOTOR BEARING	OIL CUP	2 EA.	O	"20"	24 AK	14 J M	19 J M	30 J M								
SHAFT BEARING	GREASE CUP	1 EA.	G	MANUFACTURERS SPECIAL	7 AK	14 J M	19 J M	30 J M								
FLOATING COVER																
ROLLER (6) BEARINGS	PIN	2 EA.	G	"CUP"												
VALVES																
6" SCUM WELL PLUG VALVE	PLUG	1	G	PETROLEUM JELLY	←		KEEP VALVES TURNING EASILY									→
OTHER 6" PLUG VALVES	PLUG	1 EA.	G	MANUFACTURERS SPECIAL	←		KEEP VALVES TURNING EASILY									→
GAS LINE PLUG VALVES	PLUG	1 EA.	G	MANUFACTURERS SPECIAL	←		KEEP VALVES TURNING EASILY									→
WORM STEM VALVES	"SURFACE"	1 EA.	G	"CUP"	←		KEEP STEM SURFACE COVERED									→
PRESSURE RELIEF F.T. UNITS																
PRESSURE-VACUUM F.T. UNIT	LEATHER DIAPHRAM	1	O	NEATSFOOT		15 J M		23 J M								
FLAME TRAP UNIT (SPRING)	"SURFACE"	1	G	"CUP"		15 J M		23 J M								
PRESSURE F.T. UNIT	LEATHER DIAPHRAM	1	O	NEATSFOOT		19 J M		23 J M								
(" ") (SPRING)	"SURFACE"	1	G	"CUP"		15 J M		23 J M								
TELL-TALE																
CHAIN	"SURFACE"	1	G	"CUP"		15 J M		24 J M								
MOTORIZED VALVE																
SLIDE	"SURFACE"	1	G	"CUP"				27 J M								
MOVING PARTS	BEARINGS	EA.	O	"90"				26 J M								
DAMPER MOTOR																
MOTOR BEARING	"OIL CUP"	1	O	S.A.E. 10		1 J M										
CHLORINATOR																
METAL	"SURFACE"	EA.	G	PETROLEUM JELLY	KEEP ALL METAL TUBING, VALVES, PARTS, ETC., COVERED.											

FERTILIZER AND FERTILITY VALUES OF SEWAGE SLUDGE

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THE use of various types of sewage sludge as sub-grade fertilizer or soil builders has been advocated for many years. Enthusiasm to use this by-product of sewage treatment has come mainly from the layman, but soil technologists and soil scientists continue to wonder why sludge is not returned to the soil for its plant food and fertility value. (Note that a distinction is made between plant food content and fertility value.) Many farmers, gardeners, florists and green-keepers have tried the material, but frequently have stopped after some years.

Sanitary engineers in general have looked at the sludge problem as a question of destruction of noxious matters rather than conservation of values. Sewage plant operators have tried to stimulate its use. There is an increasing tendency to find ways and means to utilize sludge, principally as a fertilizer filler or for soil improvement through direct application.

An inquiry to determine why the material is not used on a larger scale, especially from smaller plants, or why the use has been discontinued, seems to indicate several reasons which can be summarized as follows: (1) Insufficient knowledge of the value; (2) improper use of the material or insufficient preparation; (3) excessive claims made by the seller, or (4) lack of interest by the seller.

From a hygienic standpoint there is *no problem* if the sludge is used in a proper manner. A rather extensive inquiry made to determine whether ill-effects have been observed on animals or human beings, shows that where land disposal has been practiced for many years no disease or epidemics have occurred. This is probably due to the fact that users of large quantities of sludge have taken proper precautions. As a rule fresh sludge has been used only on forage crops and plowed under after application. Heat dried activated sludge and heat dried digested sludge appear to be safe for any reasonable use in agriculture, horticulture or floriculture, while well digested air dried sludge appears to be as safe as manures.

What Is the True Value of Sludge?

Determinations of the values in sewage sludges have chiefly been a matter of testing for the principal fertilizer ingredients (nitrogen, phosphorus and potash), while sometimes the organic matter content is taken into consideration. Users of sludge for agricultural or horticultural purposes have repeatedly called attention to the fact that the results obtained could not be entirely accounted for by the mineral or plant food constituents. The better results have been variously explained on the basis of: (1) The organic matter content of the sludge results in an increased moisture holding capacity of the soil, preventing retardation of growth or wilting during dry weather; (2) an improvement in the soil structure, especially in clay allowing more air to enter and subsequently a stimulation of oxidation or organic matter by the soil organisms; (3) introduction of large numbers of bacteria and protozoa, resulting in a speeding up of decomposition, the introduction of micro-organisms, such as molds, into the soil, making the nutrients more available for the plants; (4) introduction of certain minerals needed for plant growth; absence of weed seeds, which may utilize the available plant food.

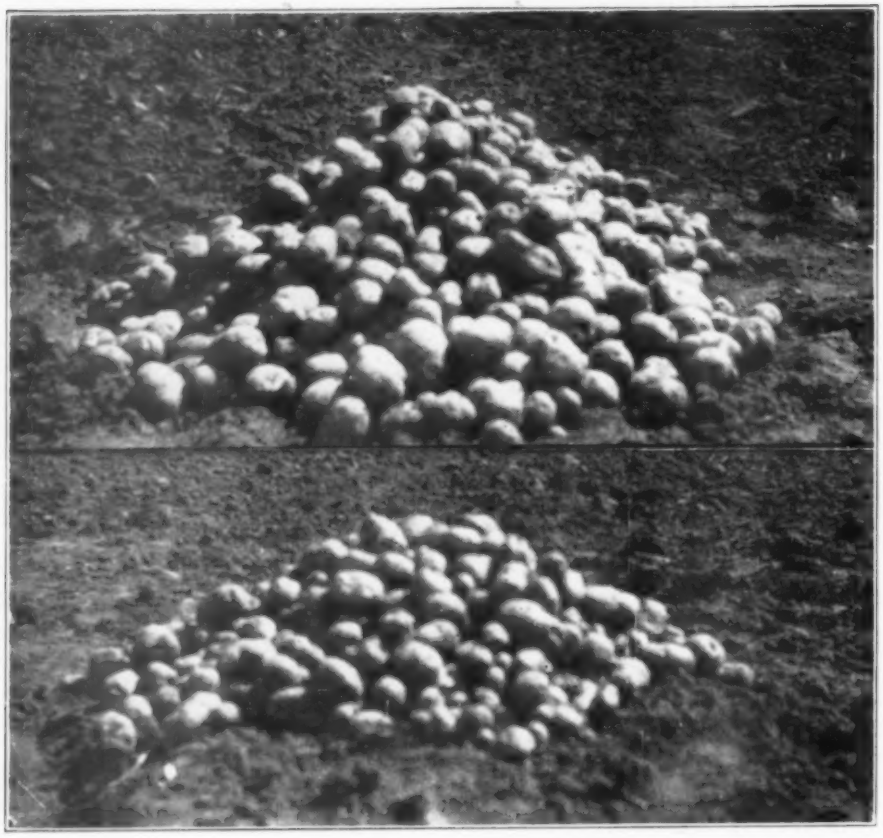
On the other side of the picture is the discontinuance of the use of sludge after several years on account of plant injury. The reasons advanced for plant injury have been mainly: introduction of poisons in the soil which were present in the sludge (certain industrial wastes); high grease content resulting in water logging and production of organic acids; burning of plants resulting from acidic decomposition products which make the soil acid.

Sludge Constituents—Major and Minor

Until a relatively short time ago it was assumed that only ten chemical elements (nitrogen, phosphorus, sulfur, calcium, magnesium, potassium, iron, carbon, hydrogen and oxygen) were indispensable for the growth of higher plants. Many other elements, if found effective, were regarded as plant stimulants. In 1914 Prof. Mazé at the Pasteur Institute in Paris showed that other elements were necessary. Not much attention was paid until in 1923, when Miss Warrington at the Rothamsted Experiment Station in England found that boron was essential for beans and several other plants. Only during the last few years has it been found that a number of plants can not complete their growth cycle without minute quantities of boron, copper, zinc, manganese, possibly molybdenum and several others. These "minor," or "accessory," or "micro-nutrient" elements have a remarkable effect on various phases of plant growth. Iron, for instance, plays a role in oxidation, copper has been reported as essential in certain oxidase systems; manganese is essential to respiration and to nitrate reduction in plants; zinc may be important in the change of carbonic acid to water and CO_2; certain metal deficiencies produce chlorosis of varied types of green plants.

A compilation of the chemical composition of sludges, including the main fertilizer constituents and the "minor" elements. is given in Table I. For comparison it should be kept in mind that the average fertilizer ingredients of barnyard manures are about 2 per cent nitrogen, 1 per cent phosphorus

Preparation and Conditioning Is Important to Marketing
For ease of handling and saleability compare the lumpy product on the left as removed from sludge drying beds with the uniformly granulated and aerated product turned out by a well-known sludge disintegrator.



A Potato Crop—With and Without

From the same area, in a field side by side, potatoes (above) were fertilized with 400 lbs./acre of Toledo's air-dried digested primary sludge, marketed under the name "Tol-e-Gro." The yield was just 200 per cent more than the pile (below) not fertilized.

(P_2O_5) and 1.5 per cent potash (K_2O). It is evident that in addition to the main fertilizer ingredients, small quantities of "minor" elements are present in the sludge which may play an important role in plant growth. The quantities of minor elements are relatively small, so that danger of poisoning the soil is absent. The quantities of lime salts present in the sludge varies with the hardness of the water supplies and the manner of sludge treatment. The amount of lime salts expressed as (CaO) may be as low as 2 per cent and as high as 12 per cent on a dry basis.

Humus Value

As a soil builder the humus content of sludge is less than that of barn-yard manure, because the ash content is greater, but still is of considerable value in sandy and heavy clay soils.

The crude fiber (cellulose, lignin, etc.), being complex insoluble carbohydrates, resist bacterial decomposition and remain longer in the soil (Table II). Most of the so-called total organic matter gradually disappears, but is of importance from the standpoint of humus accumulation and moisture holding capacity of the soil. Soils which retain a higher moisture content usually support a greater variety of plants and allow the plants to continue their growth even during dry spells.

Fats and greases are important chiefly because they make the sludge lump and interfere with the desirable uniform distribution of the sludge. Also, because grease decomposition produces acidic compounds, resulting in acidic soils. It is our experience that most of the injurious effects that may be chargeable to sludge application for a number of years are due to the accumulation of acids in the soil. The first few years these acids have a tendency to make insoluble plant foods present in the soil more available, hence produce better results than might be expected from the sludge alone. After a few years the available insoluble plant food has been reduced and the soil becomes more and more acid. Certain plants, which desire a neutral or only slightly acid soil, are retarded in their growth and finally are injured by the accumulated acidity. The simple application of agricultural lime (carbonate of lime) neutralizes this acidity. For best results in the long run, a judicious lime application every 3 or 4 years prevents a good deal of trouble. The fact that this simple remedy often has been overlooked accounts for reluctance of farmers and greenhouse growers to use sludge after a few years' trial.

Growth-Promoting Substances

Increasingly it is recognized that plants do not synthesize vitamins or their precursors as a philanthropic act for the benefit of animal or man. These substances have a function in the plant itself. The substances are generally classified as growth-promoting substances, since they may induce root development, stem elongation, cell swelling, ripening of fruit, stimulate germination and flowering, and produce other responses. Farm yard manure and decaying vegetable matter have been shown to contain various growth-promoting substances. Tests made for the presence of some of these substances in sewage sludges are summarized in Table III.

The quantities of growth-promoting substances required to affect the growth of plants are extremely small. Comparatively large applications of artificially produced compounds may even cause injury or retardation. Indole and skatole derivatives appear to be among the most effective growth-promoting substances. Indole and skatole, as well as butyric, acetic and propionic acids, are produced during decomposition of sludge and can be expected to be present. The presence of various growth-promoting substances gives to sludges a higher *fertility value* than indicated by a mere chemical analysis, which reveals only the principal *fertilizer ingredients.*

Practicing farmers have maintained for years that mineral fertilizers "burn out" the soil. What is meant is that mineral

TABLE I

Average Chemical Constituents of Sewage Solids and Sludges*

Element	Fresh Solids	Digested Sludge	Activated Sludge
Total Nitrogen (N)	4.50*	2.25*	6.20*
Phosphoric (P_2O_5)	2.25	1.50	2.50
Potash (K_2O)	0.50	0.50	0.75
Silica (SiO_2)	13.80	27.60	8.50
Iron (Fe_2O_3)	3.20	6.00	7.20
Aluminum (Al_2O_3)	2.10	4.30	3.20
Calcium (CaO)	2.70	5.70	1.70
Magnesium (MgO)	0.60	1.00	1.40
Manganese (MnO)	0.02	0.04	0.03
Sodium (Na_2O)	0.80	1.50	1.00
Titanium (TiO_2)	0.06	0.10	0.08
Copper (CuO)	0.02	0.05	0.05
Barium (BaO)	0.05	0.10	0.06
Zinc (ZnO)	0.01	0.04	0.03
Lead (PbO)	0.10	0.20	0.20
Nickel (NiO)	...	...	0.005
Cobalt (CoO)	0.0002	...	0.0002
Sulfur (So_3)	1.2	2.5	2.80
Chlorides (Cl)	0.50	0.50	0.50
Chromium (Cr_2O_3)	...	...	0.20
Arsenic (As_2O_3)	trace	trace	0.013
Boron (Br_2O_3)	...	...	0.0115
Iodine (I)	...	...	0.001

*All figures being % of each ingredient on the dry basis.

TABLE II

Composition of Sludges

Constituent*	Fresh Solids	Digested Sludge	Activated Sludge
Organic Matter	60-80*	45-60*	65-75*
Total Ash	20-40	40-55	25-38
Insoluble Ash	17-35	35-50	22-30
Pentosans	1.0	1.50	2.10
Grease and Fat (Ether)	7-35	3.5-17.0	5.0-12.0
Hemicelluloses	3.2	1.6	...
Cellulose	3.8	0.6	7.01
Lignin	5.8	8.4	...
Protein	22-28	16-21	37.5

*All figures being % of each constituent on the dry basis.
†Includes lignin, etc.

TABLE III

Presence of Growth Promoting Substances in Sludges (Relative Amounts of Single Substances)

Substance	Fresh Solids	Digested Sludge	Activated Sludge
Skatole, ppm.	1.2 -7.8	traces	none to traces
Indole, ppm.	0.12-70	0.5-1.0	0.0-0.05
Ascortic acid (Vitamin C)	++++	++++	++++
Carotene	+++	++	+
Tryptophane (free)	++++	+	++
(combined)	++++	++	+++
Tyrosine (free)	++++	+	++
(combined)	++++	++	+++
Phenyl compds.*	++++	++	++
Naphthyl Compds. †	—	—	—

*As benzoic acid; † as α-naphthol.

fertilizers stimulate the destruction of organic matter, making the plant food, plant stimulants and hormones available in greater abundance. This results in increased crop yields, but also gradually reduces the stored-up fertility of the soil. Thereby the soil becomes poorer. The value of farmyard manure is in replenishing the organic matter, "minor" elements and growth-promoting substances. Its application is of importance, therefore, in making the soil gradually richer. A similar function can be ascribed to sewage sludge. Since sewage sludge contains only relatively small amounts of the principal fertilizer ingredients crop yield cannot be as great as from mineral fertilizers, but, like other improved animal manures, it improves the soil and will continue to do so if acidity is checked by lime applications.

TABLE IV

Crops and Plants Which Have Benefited From Sludge Applications

Truck crops—	Field crops and fruits—
Squash	Corn
Tomatoes	Wheat
Turnips	Rye
Pumpkins	Barley
Beets	Turnips
Carrots	Grass
Radishes	Beets
Parsnips	Mustard
Onions	Potatoes
String Beans	Tobacco
Lima beans	Cotton
Lettuce	Apples
Spinach	Citrus fruits
Sweet corn	Strawberries
Cabbage (and others)	
Trees and shrubs—	
Maple	Berberis
Ash	Spirea
Birch	Daphne
Chestnut	Cotoneaster
Prunus	Taxus
Cornus	Several broad leaf evergreens
Jasminium	
Hydrangea	
Flowers—	
Roses	
Carnations	

(Many annual flowers respond to sludge, in some cases leaf growth is more stimulated than is flowering.)

Sludge Enrichment or Sludge Filler

The addition of mineral fertilizers to enrich sludge results in a more complete product. Not only are the necessary major plant foods present, but the required "minor" elements and growth-promoting substances are available. This combination produces a balanced fertilizer and also a soil builder. This balanced product gives higher crop yields without loss of soil fertility. Such a balanced product is of especial value for sandy and clay soils. The response of rich loamy or peaty soils to this balanced product should be less and it explains partly why experiments conducted with various crops in different soils may appear to be contradictory.

The amount of organic matter present is of importance, because of its favorable effect on the absorption capacity of the soil, and is of further interest because it is the carrier for organic nitrogen, which aids bacterial decomposition and becomes available to the plant when needed.

Crops and Plants Benefited

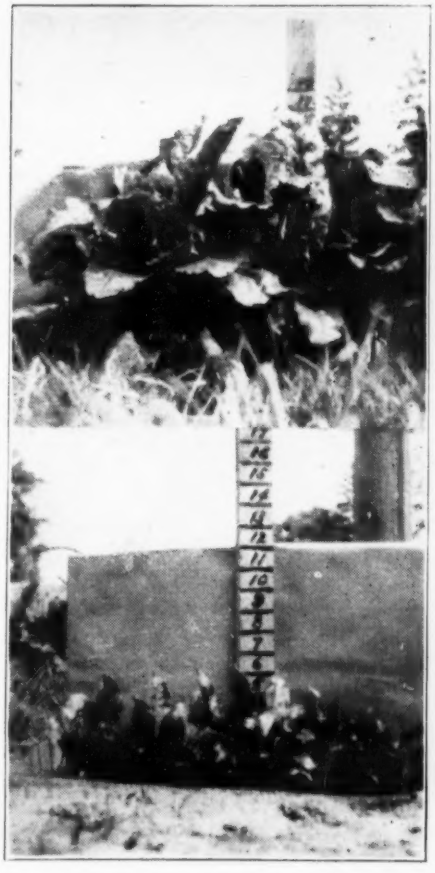
A compilation of plot experiment results and actual practice of crops and plants which have been benefited from sludge applications (Table IV) indicate that a number of grasses, root and leaf crops, trees and shrubs respond to sludge. The list is incomplete, because only those plants have been included where sludge was of *definite* value. Cases where the value was doubtful or contradictory have been disregarded. Sludge has been found to be of particular value on lawns and greens. It does not cause "burning," but small applications of lime are necessary from time to time.

The amount of sludge applied varies with the crop. For field crops the application varies from 6 to 10 tons per acre, but additions up to 40 tons per acre have produced good results. A number of nursery men have reported good results with young trees and shrubs with sludge used in a manner and in quantities such as would be used if the material were barnyard manure.

Over-All Value

The *fertility* values together with the *fertilizer* value of sewage sludges may be summarized in general as follows:

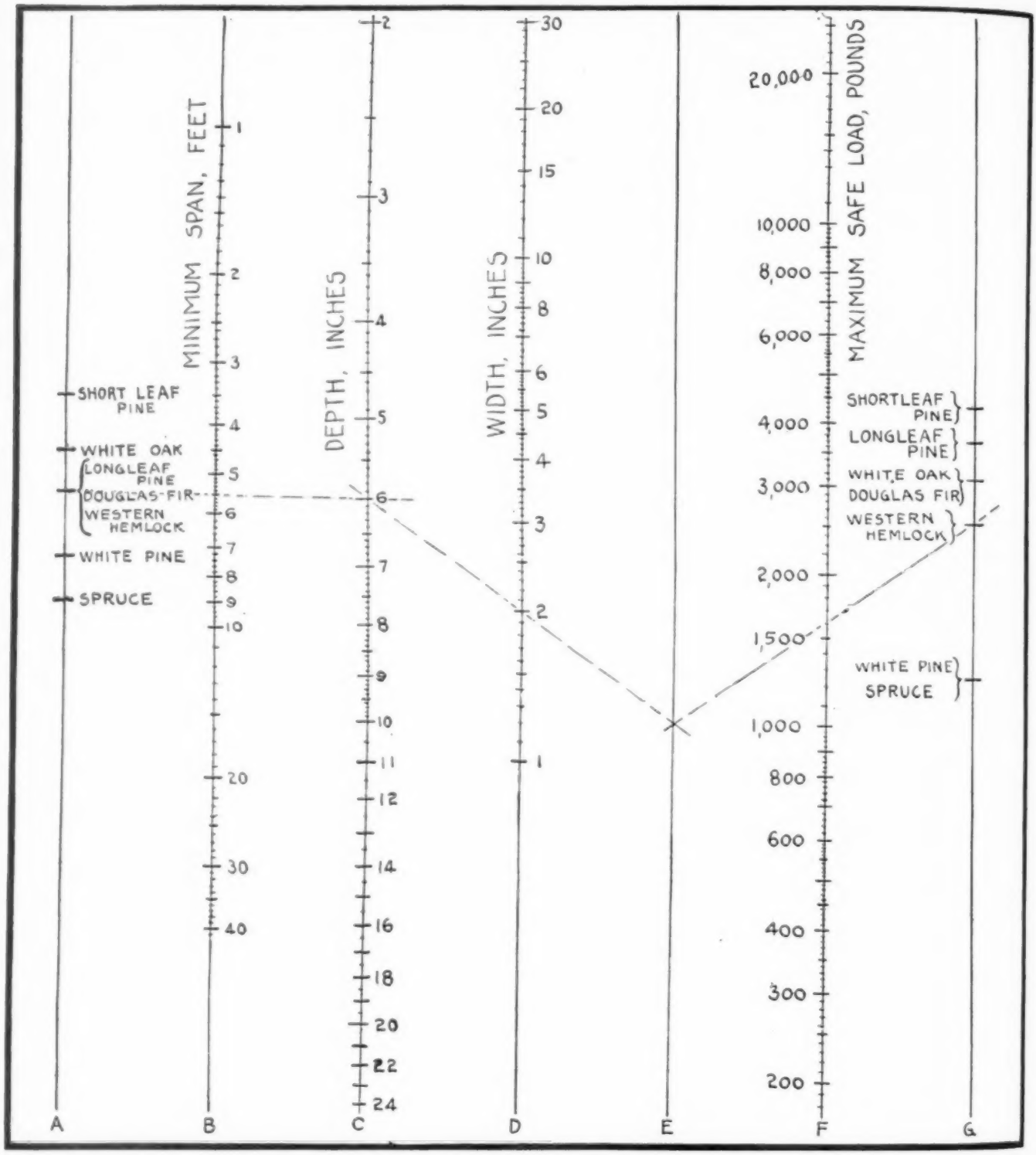
In addition to relatively small amounts of the principal fertilizer ingredients, sewage sludge contains "minor" chemical elements and growth-promoting substances essential and necessary for proper plant growth. It prevents depletion of humus and is capable of increasing the fertility of the soil. It improves the soil structure in general and increases the water-holding capacity of sandy soil in particular. The value of sludge is not the same for all soils, neither is it the same for all crops. Except for growth observations there is no adequate measuring-stick for revealing the over-all value of sewage sludges as soil improvers and growth promoters—in short, their fertility values as contrasted to their limited worth as fertilizers, based on the chemist's analysis alone.



40-Day Beet Growth Test
Below—Only water applied—100,000 gal./acre/day. Above—Sludge liquid applied—100,000 gal./acre/day. Weight increases of roots alone, 344 per cent.

SAFE LOADINGS FOR WOODEN BEAMS

Contributed by W. F. Schaphorst, M.E.



THE above chart will be found handy for many purposes—in the selection of safe beams made of ordinary woods such as shortleaf white pine, white oak, longleaf pine, Douglas fir, western hemlock, white pine, and spruce. The chart is based on data adopted by the American Railway Engineering Association for safe, uniformly loaded wooden beams of rectangular section.

Example: It is desired to hold 200 lb. per foot on a wooden beam of 2 in. by 6 in. western hemlock over a span of 5 ft. Will the beam be safe?

Run a straight line from the point in column A opposite "western hemlock" over to the depth 6 in column C. The intersection with column B shows the minimum span to be 5.5 ft. The beam will therefore be safe as regards span.

Then from the depth 6 in column C run a straight line through

the width 2 in column D and locate the intersection in column F. Then from that point of intersection run a straight line over to the point in column G opposite "western hemlock." The answer is found at the intersection with column F and is 1,600 pounds.

Since it is desired to hold only 5 × 200 or 1000 lb. on the 5 ft. beam, and since the beam will actually hold 1,600 lb., it certainly is amply safe. In fact, the chart shows that a beam made of white pine or spruce would be safe under this load.

Inversely, the chart may be used for finding any unknown factor or factors. If the kind of wood and the span are known, the first straight line through columns A, B and C gives the minimum depth of beam which must be used. If the width of beam is unknown, the line through the columns E, F, G is located next, and lastly the line through columns C, D, E gives the minimum width of beam in column D.

The weight of the beam itself is included in the safe load given in column F, hence the user of the chart need not worry about that factor.

SAFE LOADINGS FOR I-BEAMS

Contributed by W. F. Schaphorst, M.E.

THE accompanying chart reveals how much any ordinary I-Beam will hold under the very *worst* condition, with the load concentrated in the middle of the span as shown by the sketch on the chart. The chart, for the sake of safety, is based on concentrated loading.

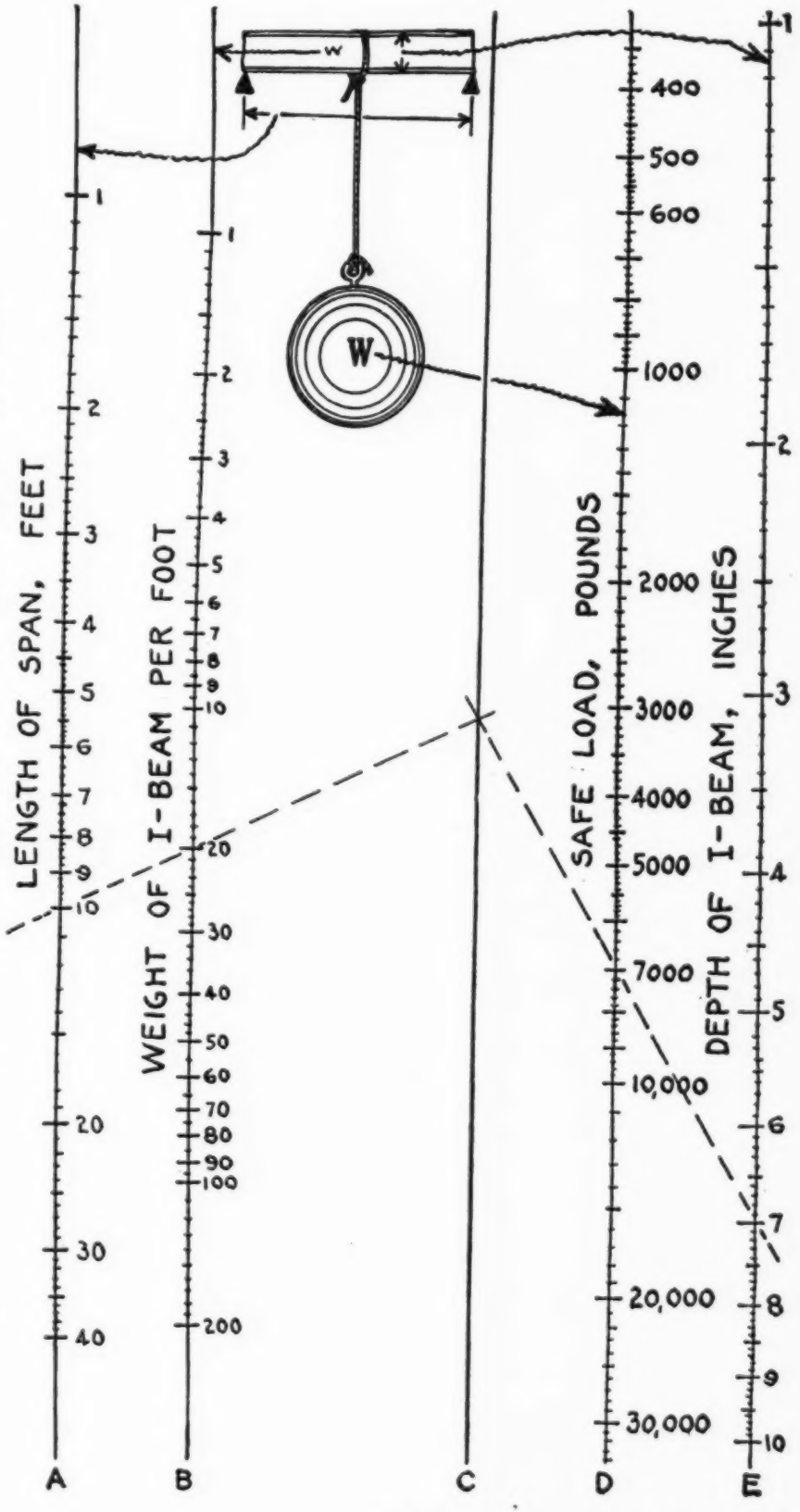
Let us suppose that a weight of 4,000 lbs. must be supported. A 7-inch I-Beam, weighing 240 lbs., is available. It is 12 feet long, and therefore weighs 20 lbs. per foot. The minimum distance between supports that can be obtained for the lifting operation is 10 feet. Is the I-Beam strong enough to lift the 4,000-lb. load?

The Answer

Run a straight line through the 10-ft. (column A) and the 20-lb. (column B) and locate the intersection in column C. Then, from that intersection in column C, run over to the 7-in. (column E). The intersection through column D shows that the I-Beam will support 7,000 lbs. Since the load to be lifted is only 4,000 lbs. the beam is amply strong. In fact, the reader can easily find, by applying the chart, that a 4-inch I-Beam, all other conditions being the same, would safely support the load of 4,000 lbs.

Similarly, it is easy to ascertain the maximum allowable span when the factors in columns B, D and E are known. Or, the necessary weight per foot of I-Beam may be determined when the factors in columns A, D and E are known. Lastly, the depth of beam is determinable when the factors in column A, B and D are known.

For loads that are "uniformly distributed"—not concentrated—the safe loads in column D may be multiplied by two. Thus, the above described beam will support a uniformly distributed load of 14,000 lbs., or 1,400 lbs. per running foot.



A USEFUL "ALL PURPOSE" PIPE CHART

By W. F. SCHAPHORST, M.E.

Newark, N. J.

ENGINEERS and operators often want to know certain things about pipe, and they want to know quickly; perhaps the cubic feet of liquid or gas flowing through the pipe per minute, the gallons per minute, the pounds of water per minute, the velocity of flow, or the exact internal diameter of the pipe regardless of its standard.

All of these quantities are more or less dependent upon each other, the important question usually being the true size of the pipe. Since pipe sizes vary as they do, standard pipe not being exact in internal diameter and extra heavy pipe being different also, it is frequently necessary to search through tables and make more or less lengthy calculations before arriving at the result. And then, after a result is arrived at, one is not always certain that the answer is correct.

Note Three Lines in Column A

Here is a chart that takes care of most of these matters in a decidedly simple way. The best way to explain the method of application of the chart is to give a problem. First, it will be observed that there are three sets of figures given in connection with the extreme left hand column, which is designated as column A. The first column of figures at the left marked "1 standard" gives the actual internal diameter of standard pipe. This column shows, for example, that the internal diameter of a 1-in. standard pipe is somewhat greater than 1 in. because the column of figures marked "2 Exact" gives the exact diameter. Thus, if we have a pipe the internal diameter of which is exactly 2 in., as used in the problem which is cited below, we use this column of figures. The next column of figures, marked "3 Extra Heavy," gives the actual internal diameter of a 1-in. extra heavy pipe as less than 1 in.

Solving a Problem

Now let us apply the chart to a problem, as follows: How much water is passing through a pipe having an internal diameter of exactly 2 in., the velocity of the water being 2 ft. per sec.?

Locate the 2 in column A over the word "exact" and from its point of intersection run a straight line through the 2 ft. per sec. in column C as shown by the slanted dotted line. This straight line intersects column B. From the point of intersection in column B run a straight line over to the identical point in column G, also as shown by the dotted line. The intersection of this perfectly horizontal line from column B to column G gives answers simultaneously in the three columns D, E, and G. It shows that according to column D, 2.6 cu. ft. per min. as flowing through the pipe. Column E shows that the volume of flow amounts to 19.5 gal. per min. And column F tells us that if it is water, the weight of that water is about 165 lb. per min.

It is evident now, on studying the chart, that if the pipe were a 2-in. standard pipe instead of being exactly 2 in., the horizontal line from column B to column G would be slightly lower and the three quantities in columns D, E, and F would be slightly greater. On the other hand, it is evident that if a 2-in. extra heavy pipe were used instead of a 2-in. exact, the horizontal line from column B to G would be raised slightly above its shown position and the three quantities in columns D, E, and F would therefore be slightly less.

Working the Scales Backwards

Inversely, if any quantity in columns D, E, and F is known and it is desired to determine the velocity per second of flow through the pipe, this same chart can be used with equal ease. First run the horizontal line through the known point in D, E, or F, and then through the located point in column B run a straight line from the known pipe diameter and the intersection with column C immediately gives the velocity of the liquid in feet per second.

Or if you wish to select a pipe size, knowing any one of the quantities in D, E, or F, and having decided upon the velocity of flow, it is perfectly evident what to do.

Use as a Conversion Chart

At the same time it will be observed that this chart can be conveniently employed as a conversion chart. For example, how many gallons in 2.6 cu. ft.? The dotted horizontal line already drawn shows that the answer is about 19.5 gal., which is also equivalent to about 165 lb. of water. At the same time this chart gives a visual demonstration of the relationship between pipe sizes—standard, exact, and extra heavy. By using this chart one can quickly "read off" the internal diameter of a standard or extra heavy pipe.

The range of this chart is great enough to take care of almost any problem one may encounter. The standard pipe sizes range from ⅛ in. to 15 in., and the velocities from 0.3 to 30 ft. per second.

In the event that the liquid is other than water, multiply the weight of water by the density or specific gravity of the liquid and you then have the weight of the desired liquid. Thus, for example, if it is an oil having a specific gravity of 0.9 we would have in the above problem $165 \times 0.9 = 148.8$ pounds of oil.

Formulas

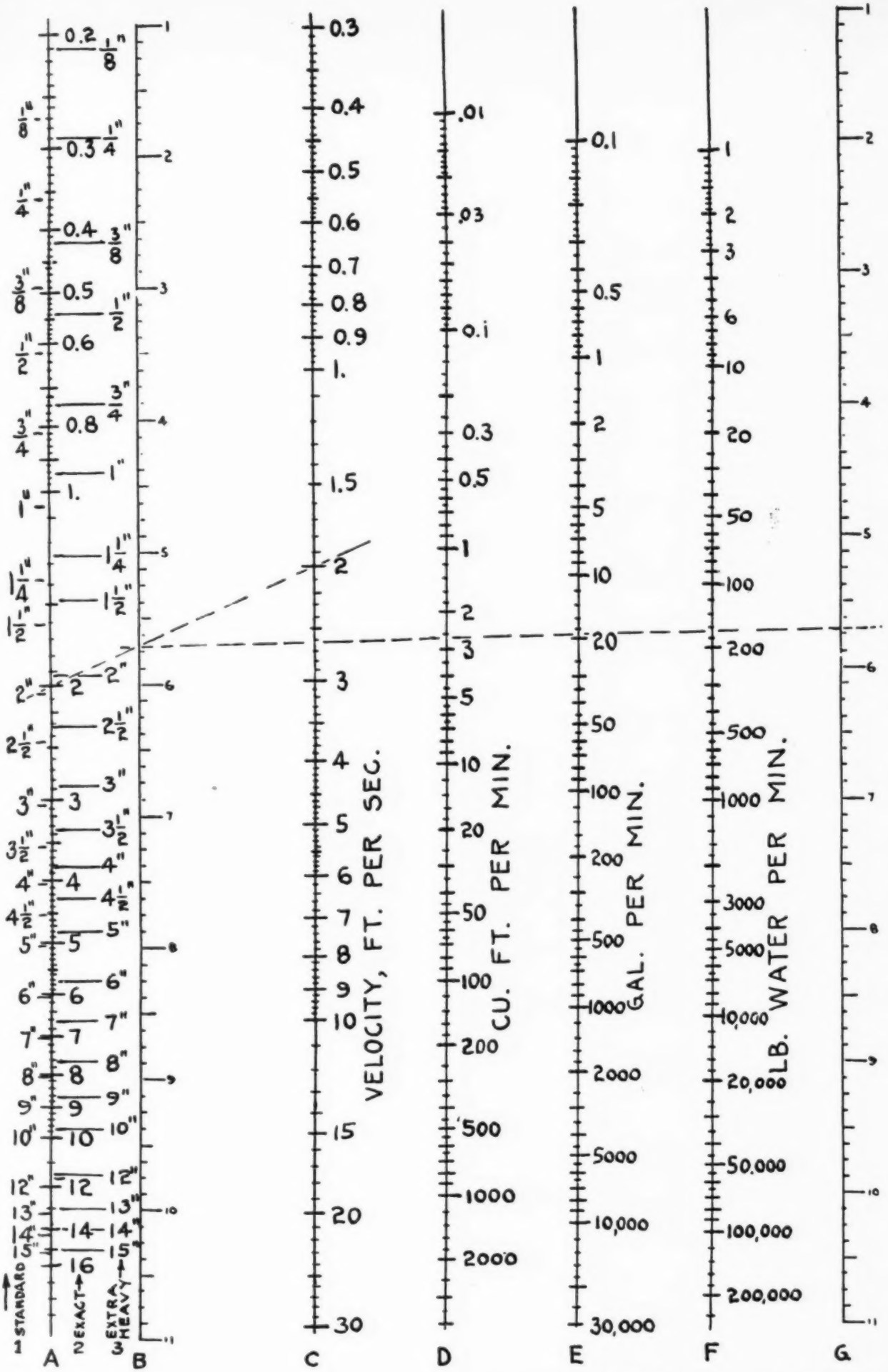
And finally, should one prefer to use formulas rather than this chart, either for solving the problem directly or for checking the results taken from the chart, here are the formulas on which the chart is based:

$$Q = 2.45\ d^2\ V$$

where Q = gallons per minute;
d = internal diameter of pipe, inches;
V = velocity of liquid, feet per second.

Cu. ft. per min. $= 0.327\ d^2\ V$

Lb. water per min. $= 20.4\ d^2\ V$


A
B
C
D
E
F
G
1 STANDARD
2 EXACT
3 EXTRA HEAVY
VELOCITY, FT. PER SEC.
CU. FT. PER MIN.
GAL. PER MIN.
LB. WATER PER MIN.

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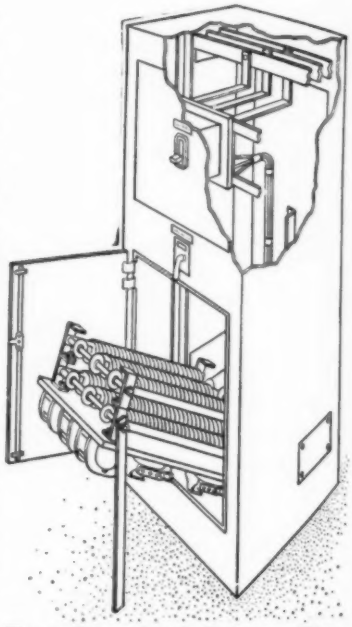

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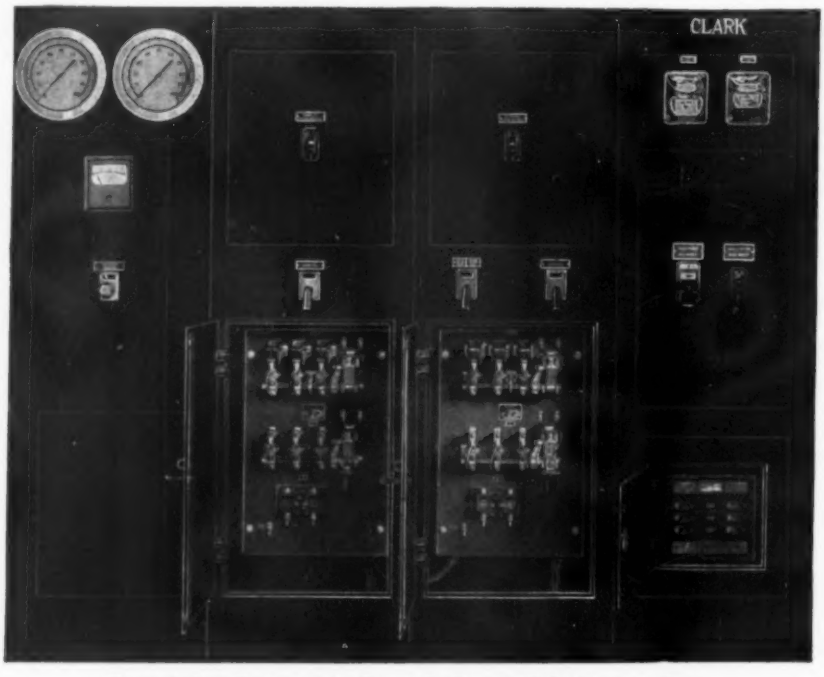
← INCOMING LINE CUBICLE



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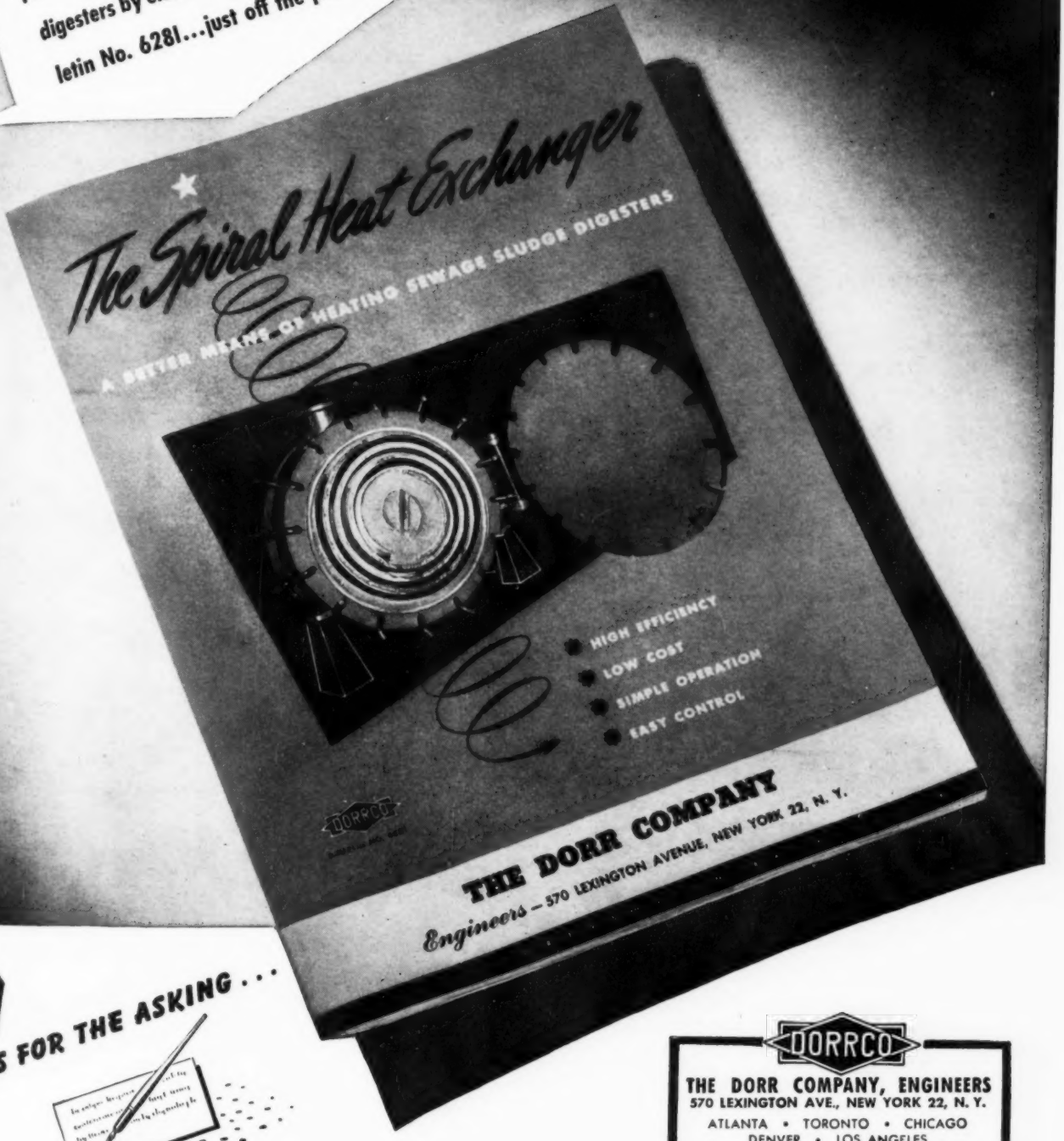

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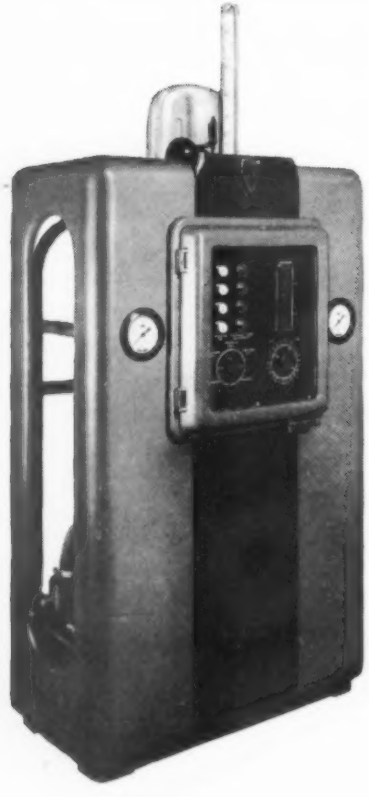

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